PROCEEDINGS

OF THE

American Institute

OF

Electrical Engineers.

Published monthly by the A. I. E. E., at 33 W. 39th St., New York, under the supervision of

THE EDITING COMMITTEE

GEORGE R. METCALFE, Editor

Subscription. $10 00 per year for all countries to which the bulk rate of postage applies.
All other countries $12.00 per year.
Single copy $1.00.
Subscriptions must begin with January issue.
Changes of advertising copy should reach this office by the 15th of the month, for the issue of the following month

Vol XXXIII July, 1914 No. 7

The Detroit Convention

The thirty-first Annual Convention of the Institute was held at the Hotel Pontchartrain, Detroit, Mich., June 22—26, 1914. The convention was an unqualified success in attendance, quality of papers and discussions presented, and the enjoyment afforded by the numerous features arranged by the local committees.

There were six technical sessions, and the number of papers on the program was limited so that there was ample time for a thorough discussion of all the subjects under consideration.

The total number of members and guests in attendance was 483, of which 302 were members and 181 were guests; of the latter number 100 were ladies. The local registration from the city of Detroit was 210, of which 43 were members and 167 guests, 64 of whom were ladies.

Monday Evening

The first scheduled event on the program was a reception and dance at the Hotel Pontchartrain on Monday evening, June 22. In the receiving line were Vice-President A. W. Berresford, of Milwaukee, Mrs. Paul M. Lincoln, of Pittsburgh, Vice-President S. D. Sprong, of Brooklyn, Mrs. C. C. Owens, of Detroit, Mrs. Farley Osgood, of Newark, and Secretary F. L. Hutchinson, of New York. About 100 persons were present on this occasion, and an excellent orchestra provided music for dancing, which was continued until after midnight.

Tuesday Morning

The convention was called to order at 10 o'clock Tuesday morning by President C. O. Mailloux, who gave his Presidential Address, entitled "The Evolution of the Institute and Its Members." Beginning with a historical sketch of the accomplishments of the Institute he proceeded to consider the evolution of the organization and spoke of its rapidly enlarging field in all directions. In conclusion he urged that engineers should not place too conservative an estimate upon themselves; they should develop "class spirit" and show that they are qualified to deal with public questions and to occupy a social plane parallel to those occupied by the members of the older professions. President Mailloux's address will be printed in full in a future issue of the PROCEEDINGS.

Following his address President Mailloux turned the balance of the session over to the Committee on Electricity in Marine Work, and Mr. H. A. Hornor of that committee presided during the rest of the session. The first paper on the program, "Electric Heating as Applied to Marine Work", by C. S. McDowell and D. M. Mahood, was abstracted by Mr. Mahood. Mr. H. C. Ford then read his paper on "The Electrically Driven Gyroscope in Marine Service." Both of these papers drew out considerable discussion.

Tuesday Afternoon

Tuesday afternoon was devoted to tennis and golf preliminaries and to automobile trips which were taken by a large proportion of those in attendance.

The local committee provided a large number of cars, which made tours through the boulevard system of Detroit, visiting a number of the automobile plants, Belle Isle, the island park of the city, Aqueduct Park, and other points of interest.

Tuesday Evening

The convention was called to order at 8:15 Tuesday evening, the session being in charge of the Industrial Power Committee. Chairman R. Tschentscher of this committee presided. Three papers were presented at this session, namely "Direct-Current Motors for Coal and Ore Bridges," by R. H. McLain, "Method of Keeping Down Peaks on Power Purchased on a Peak Basis", by T. E. Tynes, and "Concatenated Induction Motors for Rolling Mill Drive," by William Oschmann. Following the discussion of these papers President Mailloux made some brief remarks on the International Electrical Congress to be held at San Francisco in 1915, and made a strong plea for the members of the Institute to support this Congress. The evening session concluded with a moving picture exhibition accompanied by a talk by Mr. W. A. Phillis of Pittsburgh, Pa. Three films were shown and explained by the speaker, beginning with views showing the method of prospecting tor ore by drilling and showing by successive stages the handling and reduction of the ore and the manufacture of finished pipe.

Wednesday Morning

The Electrophysics Committee was in charge of the technical session of Wednesday morning, which was called to order at 10:00 a.m., Dr. J. B. Whitehead presiding. Mr. F. W. Peek, Jr., abstracted his paper, "The Sphere Gap as a Means for Measuring High Voltage," and Dr. Whitehead summarized the paper "The Electric Strength of Air—V" by J. B. Whitehead and W. S. Gorton, and also, in the absence of the authors, the paper "Sphere-Gap Discharge Voltages at High Frequencies" by J. C. Clark and H. J. Ryan. All of the three papers were discussed together, and at the close of the discussion Dr. Whitehead described some remarkable experiments recently made by Dr. Kamerlingh Onnes of Leyden. A short-circuited coil of lead wire was submerged in liquid helium and maintained nearly at absolute zero temperature, thus reducing its electrical resistance to zero. A current of electricity was caused to flow in the coil by magnetic induction and after the magnetizing influence was removed the current persisted, and he stated that apparently the current might have continued indefinitely. The experiment was concluded at the end of 4½ hours.

Wednesday Afternoon and Evening

The rest of the day was devoted to a boat trip, sports and supper on Bois Blanc Island and a moonlight trip up the Detroit River in the evening, which are more fully described below.

Thursday Morning

The Engineering Data Committee was in charge of the session on Thursday morning, at which Mr. Percy H. Thomas presided as chairman. Two papers were scheduled for this session, namely, "Data on High-Tension Transmission Systems", by Percy H. Thomas, and "Specifications for Inspection and Test of High-Tension Line Insulators", by the Engineering Data Committee. Both of these papers were outlined by Mr. Thomas and an extensive discussion ensued.

Thursday Afternoon

The first part of the Thursday afternoon session was in charge of the Prime Movers Committee and was presided over by Mr. H. G. Stott, who abstracted the paper on "Present Status of Prime Movers" by W. S. Gorsuch, R. J. S. Pigott and himself. Following the discussion on this paper Mr. W. I. Middleton abstracted the paper on "Voltage Testing of Cables" by Chester

L. Dawes and himself. Both of these papers were discussed at considerable length.

Thursday Evening

The convention was called to order Thursday evening at 8:15 p.m. for the presentation of the Edison Medal and Past-Presidents' badges. The Edison Medal was awarded to Dr. Charles F. Brush of Cleveland, Ohio, for meritorious achievement in the invention and development of the series arc lighting system. The presentation speech was made by President Mailloux, who described at considerable length many of Dr. Brush's inventions, saying that he laid the foundation for the entire industry of electric lighting. President Mailloux referred to the conflict which was waged between the arc and incandescent lighting systems and noted that it was a remarkable coincidence that the names of Brush and Edison should now be coupled after time has obliterated the feeling of contention which existed thirty years ago. Dr. Brush responded briefly, expressing his appreciation of the honor which had been conferred upon him.

The Edison Medal was designed by James Earle Frazer, and bears on its obverse a portrait of Thomas A. Edison and on its reverse an allegorical conception, "The Genius of Electricity Crowned by Fame." The first award was made in 1909 to Elihu Thomson, the second to Frank J. Sprague, the third to George Westinghouse, the fourth to William Stanley, and the fifth to Charles F. Brush.

President Mailloux next handed Past-Presidents' Badges to Secretary Hutchinson with the request that they be presented to Gano Dunn and Ralph D. Mershon, who were unable to attend the convention. Mr. Farley Osgood then presented President Mailloux with his badge, with a few pleasantly worded remarks. The introduction of President-elect Paul M. Lincoln of Pittsburgh followed the presentation of the Past-Presidents' badges. Mr. Lincoln spoke briefly, making an earnest plea for the cooperation of all the members of the Institute in making his administration a success. The meeting then adjourned to the basement dining room in the hotel where a cabaret was enjoyed and a number of prizes were awarded to winners of various sports.

Friday Morning

The last technical session of the convention was called to order at 10 o' clock Friday morning by President Mailloux, and a paper on "Sterilization of Water by Ultra-Violet Rays" by M. von Recklinghausen was presented under the auspices of the Electrochemical Committee. The paper was illustrated with lantern slides, and at the close of the discussion Mr. Frank F. Fowle, chairman of the Telegraphy and Telephony Committee, presided while a paper was presented by Prof. Carl Kinsley, entitled "A High-Speed Printing Telegraph System." Prof. Kinsley gave a demonstration of the receiving end of his apparatus, which uses a perforated tape. President-elect Lincoln then took the chair while Mr. Fowle gave an abstract of his paper on "Toll Telephone Traffic." At the close of the discussion on this paper Mr. Lincoln declared the technical sessions adjourned.

Section Delegates

For the purpose of providing an opportunity for the delegates to exchange views informally in regard to the work of Section organizations, arrangements were made for the delegates and the members of the Sections Committee to take luncheon together on June 23, 24, 25 and 26. These informal discussions were of great interest to all who attended, and resulted in an exchange of experiences by the various delegates regarding problems which confront them in connection with Section affairs. A number of resolutions were adopted and referred to the Board of Directors.

The regularly scheduled conference of Section delegates was held on the afternoon of Friday, June 26. Chair-

man Paul M. Lincoln called upon each delegate for a brief statement relating to the conditions in the Section which he represented. At a later date a report of this conference, together with a resume of the actions taken at the luncheons, will be prepared and will be forwarded to the delegates, Section officers and other members who may be interested.

A complete list of the delegates present at the convention is as follows:

Atlanta	A. M. Schoen
Baltimore	J. B. Whitehead
Boston	G. W. Palmer, Jr.,
Chicago	D. W. Roper
Cleveland	E. H. Martindale
Detroit-Ann Arbor	H. H. Norton
Fort Wayne	P. O. Smith
Indianapolis-LaFayette	R. Fleming
Ithaca	W. G. Catlin
Los Angeles	E. R. Northmore
Lynn	E. R. Berry
Madison	C. M. Jansky
Minnesota	W. T. Ryan
Panama	F. C. Clark
Philadelphia	H. A. Hornor
Pittsburgh	A. M. Dudley
Pittsfield	W. W. Lewis
Portland, Ore.	G. P. Nock
St. Louis	F. J. Bullivant
Schenectady	George H. Hill
Seattle	S. C. Lindsay
Spokane	J. B. Fisken
Toledo	Max Neuber
Toronto	W. T. Wright
Urbana	Morgan Brooks
Vancouver	E. M. Breed

Entertainment

An attractive program of entertainment features was provided by the several local committees which had been appointed for this purpose. In addition to the features which are specifically referred to elsewhere, opportunity was afforded to all who desired to visit the many operating and manufacturing plants in Detroit, including the numerous automobile companies.

Automobiles were available at all times for members and guests for shopping trips or sight-seeing tours.

Wednesday afternoon, June 24, was set aside for an outing to Bois Blanc Island. The special steamer which had been chartered for the purpose by the Outing Committee, left Detroit about 2:30 p.m. Upon arrival at the Island, baseball and other sports were indulged in, after which supper was served to all, and the entire party re-embarked for the return trip about 7:30 p.m. This trip was purposely extended into a moonlight excursion on the Detroit River, of several hours' duration, in the course of which many of the party enjoyed dancing upon the upper deck.

At the meeting of the Board of Directors held on Thursday morning, June 25, an account of which appears elsewhere in this issue, the following resolutions were adopted and were unanimously ratified at the final convention session on Friday morning:

Resolved, that the Board of Directors of the American Institute of Electrical Engineers, representing the membership at large, and more especially the members and guests in attendance at the Annual Convention in Detroit, hereby expresses its hearty appreciation of the excellent arrangements made by the Local Committee for the comfort and entertainment of the members and guests of the Institute during the convention, and

Resolved, that the thanks and appreciation of the American Institute of Electrical Engineers be likewise tendered the Detroit Edison Company, the General Electric Company, the Westinghouse Electric and Manufacturing Company, the Anderson Electric Car Company, the Cadillac Motor Car Company, The Chalmers Motor Company, the Ford Motor Company, the Hudson Motor Car Company, the Lozier Motor Company, the Packard Motor Car Company, the Detroit Golf Club, the Detroit Tennis Club, and the management of the Hotel Pontchartrain for the courtesies which they have so cordially extended.

Winners of Prize Contests at Convention.

Golf: Mr. J. C. Mock, of Detroit, won first prize in the golf tournament, which entitles him to have his name inscribed upon the Mershon Golf Trophy. This cup becomes the property of any person winning the golf

championship in two different years at the Institute convention. (It was won for the first time in 1913 by Mr. A. M. Schoen, of Atlanta, Ga.) Mr. J. H. Livsey, of Detroit, won the second prize. Mr. J. G. Biddle, of Philadelphia, won the prize for the highest gross score, and Mr. Farley Osgood, of Newark, N.J., the prize for the second highest score. Mr. F. A. Scheffler, of New York, won the consolation golf prize.

Ladies' Putting Contest: The first prize was won by Mrs. D. D. Ewing, LaFayette, Ind., the second by Mrs. Paul M. Lincoln, Pittsburgh, Pa.

Tennis: The tennis tournament was won by Mr. Charles T. Mosman, of Boston. Mr. J. R. Bibbins, of Chicago, won the second prize.

Ladies' Card Party: The first and second prizes in auction bridge were won by Mrs. E. R. Berry, of Lynn, and Mrs. J. H. Livsey, of Detroit, respectively.

The first prize in hearts was won by Mrs. A. Oakes, of Detroit; the second by Mrs. F. W. Peek, Jr., of Schenectady.

Baseball: The baseball game at Bois Blanc Island between the "Never-Wases", Captain Osgood, and the "Has-Beens," Captain Hall, resulted in a victory for the former, by a score of 32 to 6. (More or less.)

The fortunate spectators were treated to an exhibition of numerous new and brilliant plays, and the high efficiency of the players was frequently demonstrated by the ease with which hits that in a professional game could only result in a single base, were successfully extended to two or three bases, and even home-runs, by the masterly cooperation of the opposing fielders.

The prizes were awarded as follows: Longest hit, Professor A. S. Langsdorf, of St. Louis, Mo.; most hits, P.H. Chase, Newark, N.J.; most runs, Professor A. N. Topping, LaFayette, Ind.; most errors, Farley Osgood, Newark, N.J.

Baseball Throwing: The ladies' contest for the longest baseball throw was won by Mrs. W. D. Sanderson, of Detroit.

Rooster Race: This interesting contest was won by Mr. A. E. Roach, of Detroit.

Automobile Trip to the Convention: The prize for the longest automobile trip to the convention was awarded to President-elect Paul M. Lincoln of Pittsburgh.

Pacific Coast Convention, Spokane, Wash.

The various committees having in charge the arrangements for the Pacific Coast Convention to be held in Spokane Sept. 9-11, 1914, jointly with the annual Convention of the Northwest Electric Light and Power Association, are actively at work.

As previously announced, the Transportation Committee has made arrangements with the railroads for reduced rates.

The Entertainment Committee is making elaborate preparations for the entertainment of visiting members and ladies, details of which will be announced later.

The Papers Committee announces that the following papers have been promised:

A Distribution System fo Power Purposes, by F. D. Nims.

Electrical Application in the Lumber Industry, by E. F. Whitney.

Operation of the Butte, Anaconda and Pacific 2400-Volt D-C. Railway, by J. B. Cox and C. A. Lemmon.

Considerations in the Application and Control of Electric Motors for Gold Dredges, by Girard B. Rosenblatt.

The Effect of Delta and Star Connections upon Transformer Wave Forms, by Leslie F. Curtis.

Tran mission Economy, by Magnus T. Crawford.

A paper, the title of which has not been announced, on the subject of the Big Creek Development of the Pacific Light and Power Corporation, by Edward Woodbury.

A paper on some telephone subject by A. H. Griswold.

There will be one joint session with the N. E. L. and P. Association at which that organization will furnish the papers, and announcement of the subjects will be made later.

Directors' Meeting, Detroit, Mich., June 25, 1914

A meeting of the Board of Directors was held at the Hotel Pontchartrain, Detroit, Mich., during the Annual Convention, on Thursday, June 25, 1914, at 9:00 a.m.

There were present President C. O. Mailloux, New York; Vice-Presidents A. W. Berresford, Milwaukee, Wis., S. D. Sprong, Brooklyn, N.Y., and H. H. Barnes, Jr., New York; Managers F. S. Hunting, Fort Wayne, Ind., Farley Osgood, Newark, N.J., J. Franklin Stevens, Philadelphia, Pa., William B. Jackson, Chicago, Ill., L. T. Robinson, Schenectady, N.Y., and Secretary F. L. Hutchinson, New York.

The action of the Finance Committee in approving monthly bills amounting to $10,681.62 was ratified.

Petitions were presented from Professor H. P. Wood, of the Georgia School of Technology, Atlanta, Ga., and Professor L. J. Corbett, of the University of Idaho, Moscow, Idaho, requesting authority to organize Branches at the institutions named.

Upon the recommendation of the Sections Committee the desired authorization was granted.

Upon the recommendation of the Board of Examiners, the Board of Directors transferred one member of the Institute to the grade of Fellow and eight to the grade of Member, elected eight applicants as Members and 100 as Associates, and ordered the enrolment of 78 students, in accordance with the lists printed in this issue of the PROCEEDINGS.

All Institute committees, whose term of office under the constitution expired at this directors' meeting, were reappointed by President Mailloux to serve until the expiration of the current administrative year, July 31, 1914.

A considerable amount of other business was transacted by the Board, reference to which will be found under proper headings in this and future issues of the PROCEEDINGS.

International Electrical Congress, San Francisco, 1915

Preparation for the International Electrical Congress to be held in San Francisco September 13-18, 1915, is proceeding along several lines. This Congress was authorized by the International Electrotechnical Commission and the Turin Electrical Congress in Turin, Italy September, 1911, and is being organized by the American Institute of Electrical Engineers. The Committee on Program is making excellent progress in the formulation of its program for each of the twelve sections dealing with the several aspects of electrical engineering.

The membership now numbers approximately 300. All who have been elected to membership have received membership cards. The Committee on Transportation is engaged in providing for special trains to San Francisco in 1915 for the convenience and accomodation of delegates to the Congress. During the past few weeks there was added to the committees having charge of the several features of the organization work, a Committee on Editing and Publication.

The Committee on Pacific Coast Relations has arranged for the appointment of a Sub-Committee on Hotel Arrangements. This committee will have charge of hotel reservations for delegates to the Congress and to the meeting of the International Electrotechnical Commission which is to be held during the week preceding the Congress.

Members of the Institute are requested to apply for membership in the Congress. An application form

will be found in each copy of the PROCEEDINGS for April, 1914. Communications regarding the Congress may be addressed to Mr. Preston S. Millar, Secretary-Treasurer, 80th Street and East End Avenue, New York, N. Y.

International Engineering Congress, 1915

Among the general subjects to be treated before the International Engineering Congress, to be held in San Francisco, Cal., September 20 to 25, 1915, probably the one having the broadest interest is that of Materials of Engineering Construction, which enters into all phases of engineering activity.

The list of topics which will be treated in this section is as follows:

(1) Timber.

(2) Preservative Treatment of Timber.

(3) Substitutes for Timber in Engineering Construction.

(4) Brick in Engineering Structures.

(5) Clay Products in Engineering Structures.

(6) Probable and Presumptive Life of Concrete Structures made from Modern Cements.

(7) Aggregates for Concrete.

(8) Slag Cement.

(9) Waterproof Concrete.

(10) Cements containing Additions of Finely Ground Foreign Material.

(11) Economics of the World's Supply of Iron.

(12) The Life of Iron and Steel Structures.

(13) The Employment of Special Steel in Engineering Construction.

(14) The Place of Copper in the Present Engineering Field, and the Economics of the World's Supply Thereof.

(15) Alloys and Their Use in Engineering Construction.

(16) Aluminum in Engineering Construction.

(17) The Influence of the Testing of Materials upon Advances in the Designing of Engineering Structures and Machines.

(18) Cement Testing.

(19) Testing of Metals.

(20) Testing Full-Sized Members.

(21) Proof Testing of Structures.

The papers to be presented from the United States have already been arranged for from the recognized leading authorities on the various topics. Arrangements for the papers from foreign authors are being rapidly concluded, and the aggregation of papers which will be presented will constitute a broad review of the field and be of the highest value.

Marked interest in the Congress from foreign countries continues, and there is every evidence that the attendance from abroad will be large. It is hoped that all engineers in this country who have not yet subscribed as members of the Congress will give the matter their immediate attention and favorable action.

Full information concerning the Congress, the price of subscription, and the arrangement for purchase of volumes of the proceedings, may be obtained by addressing the Committee of Management, as follows:

International Engineering Congress, 1915,
Foxcroft Building,
San Francisco, Cal.,
U. S. A.

Past-Presidents of the Institute Honored

The president and three past-presidents of the A. I. E. E. have recently had honorary degrees conferred upon them by universities. President C. O. Mailloux and Mr. L. B. Stillwell, president during 1909-10, received the honorary degree of doctor of science from Lehigh University on June 9. Mr. Gano Dunn, president during 1911-12, and Mr. Francis B. Crocker, president during 1897-98, received the honorary degree of master of science from Columbia University on May 29, 1914.

Pittsfield Meeting of the Institute, May 28-29, 1914

The 296th meeting of the Institute was held in Pittsfield May 28 and 29, 1914, under the auspices of the Pittsfield Section. Eight papers were presented, seven of them relating to the general subject of Y vs. delta connections. The Maplewood Hotel was used as headquarters, and there all the sessions were held.

Professor D. C. Jackson presided at the first session, which was held on Thursday afternoon, and President-elect Mr. P. M. Lincoln at the Friday morning session. The final session, which was held on Friday evening, was presided over by President Mailloux.

The total registered attendance at the meeting was 177, including 84 engineers from outside of Pittsfield.

At the Thursday afternoon session, three papers were presented: *Experiences with Line Transformers*, by Mr. D. W. Roper; *Harmonic Voltages and Currents in Y- and Delta-Connected Transformers*, by Mr. R. C. Clinker; and *Inheren Vol:age Relations in Y and Delta Connections*, by Messrs. Royal W. Sorensen and Walter L. Newton.

At the Friday morning session the following papers were presented: *Experience of the Pacific Gas and Electric Company with the Grounded Neutral*, by Messrs. J. P. Jollyman, P. M. Downing and F. G. Baum; *Influence of Transformer Connections on Operation*, by Mr. Louis F. Blume; and *A Study of Some Three-Phase Systems*, by Mr. Charles L. Fortescue.

The Friday evening session included a paper by Mr. T. S. Eden on *Relative Merits of Y and Delta Connections for Alternators*, and a paper on *Delta and Y Connections for Railway Transmission and Distribution Systems*, by Mr. Cassius M. Davis. After the discussion of the last paper Mr. Percy H. Thomas gave a very interesting summary of the subject, including a statement of the causes of the triple harmonics and the effect of such harmonics upon the operation of three-phase systems.

The principal entertainment feature of the meeting was the annual dinner of the Berkshire County University Club which was held at the Maplewood Hotel Thursday evening. About 230 men were present, including some 75 visiting engineers. The principal speaker of the evening was Mr. William Stanley of Great Barrington, the founder of the Stanley Electric Manufacturing Company, which is now the Pittsfield Works of the General Electric Company. Short speeches were also made by Mr. P. M. Lincoln and Professor D. C. Jackson. After the dinner a dance was held.

Among the other entertainment features were the tea for the visiting ladies and those from Pittsfield on Thursday afternoon and a motor trip for the ladies on Friday afternoon The golf and tennis facilities of the Country Club were placed at the disposal of the visitors on Friday afternoon.

During the meeting a group photograph of the visiting and local engineers was taken by Mr. Burt, the photographer of the Pittsfield Works of the General Electric Company. Copies may be obtained from Mr. Burt at the price of 50 cents for mounted and 35 cents for unmounted photographs.

The Engineer—The Translator of Science

By William Stanley*

Engineering may be defined as the art of making Nature obedient. There are, therefore, as many fields of engineering as there are phases of natural phenomena. A few years ago our limited physical insight did not fully disclose the close relationship that binds all phenomena together. We seemed to think that electrical engineering was a limited subject—that the electrical en-

*Extract from address made at Annual Dinner of Berkshire County University Club, at which members of the A. I. E. E. were guests, May 28, 1914.

gineer pursued a certain set of phenomena which he, so to speak, owned; but now with our wider vision we realize that by whatever surname he be classified, he deals with such varied and universal phenomena that he must be known by a broader and more comprehensive title. To me, he seems the translator of science, his art being to apply the isolated discoveries of the scientific investigator to the affairs of every-day life.

It may be of interest to note, for a moment, how a new art such as electrical engineering is born, for I think the general course of events is substantially the same in a l new arts. To see the prenatal history of an art: electrical engineering had its origin in the discoveries in physics in the first half of the last century. I have always been astonished at the very small number of primary discoveries on whch electrical engineering was founded. About all that science could say to laymen about the early discoveries in electricity was that electricity appeared to move, or flow, from place to place in some substances, and would not flow, or would flow very little, in others; and that when it was stationary in matter, certain kinds of things were attracted towards the substance holding it, while when it flowed, or moved, from place to place in matter, entirely different forces of attraction appeared, which were called magnetic forces. They also knew, in early days, that moving electricity heated its conductor, while stationary electricity did not. Of course, there were a large number of subsidiary phenomena found in addition to the few that appeared to be fundamental, but it seems to me that the principal or fundamental phenomena were only those I have just stated. Now, the study of these fundamental and subsidiary phenomena furnished research workers with food for investigation for more than fifty years. Scientific investigators saw these facts and wondered what their true explanation was. To explain them they devised theories of one kind and another—more or less permanent, more or less satisfactory. They probably had little conception of the economic value of their work. They were entirely wrapped up in the problem of understanding and explaining it to others. During this period electricity was an academic pursuit. It was largely studied out of curiosity and for the speculative interest it awakened, not for technically useful purposes. It was not until these new elementary facts began to be studied by less specialized workers—it was not until the schools and colleges began to teach the elements of the subject—it was not until pure research knowledge was brought before men familiar with every-day affairs in the arts—that it began to be put to useful service. It is at this period in the history of an art that its engineering is born. The engineer differs from the scientific investigator in that he is educated in many directions, while the investigator generally has a specialized education and concentrates his study on a special branch of research. The aim of the engineer is to deal with *useful* knowledge. He is taught to value knowledge in proportion to its practical application. His standards are usefulness and efficiency. The investigator seeks to discern new knowledge and new facts whether they be useful or not. Now, the inventor, God help him, is a sort of sport from the parent stock of pure science. He links the research work of the investigator to the practical work of the engineer. Edison, Weston, Brush, Thomson, Sprague, Pupin, Hewitt, and many others are great inventors, but they are also great investigators. In my opinion, their engineering ability is secondary to their powers for research; yet one has on y to look at a Weston voltmeter or an Edison phonograph to appreciate the exquisite skill which devised them.

I wish to call your attention to the very remarkable fact, as it appears to me, that all this wonderful engineering of today—these power transmissions over hundreds of miles of distance,

the wonderful lighting, traction, telephoning and telegraphing—all these well-established branches of our art were not only founded on the discovery of a very few fundamentally new physical facts—perhaps not over a dozen—but without any definite knowledge of the nature of electricity—without knowing, in fact, whether it existed or did not exist. During the last ten years we have added a few more fundamentally new physical concepts to our little collection. We believe—we know—that electricity exists just as substance exists; that it exists in very minute pieces about one two-thousandth of the mass of the next smallest thing in nature, H; and, that it is a component element of all matter. We think it very likely that different kinds of matter owe their difference to the amount of—that is to say, the number of—grains of electricity entrained in each atom of matter—that lead and iron owe their different proportions to the difference in number, arrangement, and movement of the grains of electricity in their atoms. We know, for example, that we can drive off a large number of grains of electricity from matter by heating it under the right conditions. We know something about what these little grains are doing in a piece of copper wire, both when it is not being used as a conductor and when it is so used. And so I might go on and attempt to explain a number of *new facts* that are fundamental and that appear to me to be of the utmost importance to inventors and engineers and that will pretty soon be of enormous use to the world.

As to the future of engineering, who can say into what unexplored regions it may lead us? It seems likely that engineers in the future will deal with very different problems from those we now labor with, and with apparatus quite unlike that we now know. The discoveries in radioactivity, in high vacuo, in flames and heated bodies, give us pictures of the behavior of electricity undreamed-of in the past. Who shall say where the future field of energy-saving man will be? Shall we forever look to heat to start the motions we call work? Probably not. Shall we be able to compose or decompose matter, that is, change its quality, and save the freed energy accompanying the change? Possibly. Shall we perhaps gain a definite clue to that most inscrutable mystery—the nature or mechanism of gravitation? I believe so. Already we can generate electric waves that circle about the earth. Who knows but our mental vision may ride upon them? The tiny grains of electricity flying through a vacuum tube generate ether waves that penetrate organized matter and destroy its "life." Skilful hands are sifting and sorting these rays to beneficent purposes—that loathsome diseases, smitten by the invisible blast, may disappear. These are but the forerunners of a greater future, for engineering has an eternal future, a glorious and endless destiny, forever to translate the discoveries of science for the benefit of man.

Society for the Promotion of Engineering Education

The twenty-second annual meeting of the Society for the Promotion of Engineering Education was held at Princeton, N. J., from June 23 to 26, 1914. The proceedings covered a wide range of subjects, but the central idea brought out was that emphasis should be laid upon fundamental principles, and that education is not so much a matter of administration as of purpose and spirit.

The meeting was made notable by the attendance of official representatives of a large number of educational institutions. Institutional membership is a new feature of the society organization, inaugurated during the past year. Its purpose is to make the findings of the society more immediately applicable to the educational life of the country. The institu-

tional delegates were very enthusiastic in regard to the possibilities of this new feature of the society activity.

The following elections were made on the last day of the convention: president, Anson Marston, dean of the Division of Engineering, Iowa State College, Ames, Iowa; vice-presidents, Henry H. Norris, *Electric Railway Journal*, New York, and C. Russ Richards, acting dean of the College of Engineering, University of Illinois, Urbana, Ill.; secretary, F. L. Bishop, dean of the School of Engineering, University of Pittsburgh, Pittsburgh, Pa.: treasurer, William O. Wiley, secretary of John Wiley and Sons, New York; members of the council, R. H. Fernald, professor of dynamical engineering, University of Pennsylvania, Philadelphia, Pa., A. H. Fuller, dean of the College of Engineering, University of Washington, Seattle, Wash., A. M. Greene, Jr., professor of mechanical engineering, Rensselaer Polytechnic Institute, Troy, N. Y., E. V. Huntington, assistant professor of mathematics, Harvard University, Cambridge, Mass., Vladimir Karapetoff, professor of electrical engineering, Cornell University, Ithaca, N. Y., D. C. Miller, professor of physics, Case School of Applied Science, Cleveland, Ohio, and W. M. Riggs, president of the Clemson Agricultural and Mechanical College of South Carolina, Clemson College, S. C.

The reports of the various officers showed that the society is in a flourishing condition, the individual membership now being nearly 1400, and the institutional membership about 50. The council recommended that the 1915 meeting be held in the middle West.

Addresses Wanted

Name	Former address.
Oscar Elmore,	121 Rose Lawn Drive, Los Angeles, Cal.
A. R. Harris,	Edison Storage Battery Co., Orange, N. J.
M. G. Rees,	1428 N. Y. Life Bldg., Chicago, Ill.

Anyone who can give information that may assist in obtaining any of these addresses is requested to communicate with the Secretary of the Institute.

Recommended for Transfer, June 16, 1914

The Board of Examiners, at its regular monthly meeting on June 16, 1914, recommended the following members of the Institute for transfer to the grades of membership indicated. Any objection to these transfers should be filed at once with the Secretary.

To the Grade of Fellow

EDSTROM, J. SIGFRID, Managing Director, Allmanna Svenska Electric Co., Westeras, Sweden.

HARTMANN, FRANCIS M., Professor of Electrical and Mechanical Engineering, Cooper Union, New York, N.Y.

HENDERSON, CLARK TRAVIS, Electrical and Mechanical Engineer, Cutler-Hammer Mfg. Co., Milwaukee, Wis.

STILL, ALFRED, Professor of Electrical Engineering, Purdue University, LaFayette, Ind.

SYKES, WILFRED, Electrical Engineer, Westinghouse Electric & Mfg. Co., E. Pittsburgh, Pa.

UNDERHILL, CHARLES R., Chief Electrical Engineer, Acme Wire Co., New Haven, Conn.

WELSH, JAMES W., Electrical Engineer and Traffic Agent, Pittsburgh Railways Co., Pittsburgh, Pa.

To the Grade of Member

BIBBINS, JAMES ROWLAND, Resident Engineer, Bion J. Arnold, Chicago, Ill.

CONNETTE, EDWARD G., President, International Railway Co., Buffalo, N. Y.

DAVIES, CHARLES EDWARD, Supt. of Equipment, Great Northwestern Tel. Co., Ottawa, Ontario.

DEARBORN, RICHARD H., Head of Department of Electrical Engineering, University of Oregon; Electrical Engineer for Railroad Commission of Oregon, Eugene, Ore.

HULL, CLARENCE S., Foreman, Standardizing Laboratory, General Electric Co., San Francisco, Cal.

LINDSAY, SHERWOOD C., Electrical Engineer, Puget Sound Traction, Light & Power Co., Seattle, Wash.

Transferred to the Grade of Fellow June 25, 1914

The following Member was transferred to the grade of Fellow of the Institute at the meeting of the Board of Directors on June 25, 1914.

ROPER, D. W., Assistant to Chief Engineer, Commonwealth Edison Co., Chicago, Ill.

Transferred to the Grade of Member June 25, 1914

The following Associates were transferred to the grade of Member of the Institute at the meeting of the Board of Directors on June 25, 1914.

CREAGH, EDRIC C., Electrical Engineer, Hydro-Electric Power & Metallurgical Co., Ltd., Hobart, Tasmania.

EWING, DRESSEL D., Asst. Prof. Electrical Engineering, Purdue University, Lafayette, Ind.

LANIER, ALEXANDER C., Designing Electrical Engineer, Westinghouse Electric & Mfg. Co., Pittsburgh, Pa.

LIGHTFOOT, EDWIN N., Engineer, Cutler-Hammer Mfg. Co., New York, N. Y.

MAXWELL, J. M.S., Electrical Engineer, Glasgow, Scotland.

WARREN, J. F., Engineer in charge, Waipori Falls Power Station, Dunedin, New Zealand.

WENNER, FRANK, Associate Physicist, Bureau of Standards, Washington, D. C.

WHIPPLE, CYRUS A., General Superintendent, Municipal Light & Water System, Eugene, Ore.

Members Elected June 25, 1914

CRAWFORD, EDWARD JAMES, Assistant General Superintendent, San Joaquin Light & Power Corp., Fresno, Cal.

DODGE, HENRY PERKINS, General Manager, Ohio Electric Car Co.; res., 2155 Collingwood Ave., Toledo, Ohio.

HEATON, HERMAN C., Engineer, Sargent & Lundy, Chicago; res., 3441 Ivison Ave., Berwyn, Ill.

OWENS, PERCY R., Superintendent of Buildings, Mutual Life Insurance Co., 32 Nassau St., New York, N.Y.

PETERS, JOHN FINDLEY, Electrical Engineer, Westinghouse Electric & Mfg. Co., E. Pittsburgh; res., 206 Savannah Ave., Edgewood Park, Pittsburgh, Pa.

ROEBER, EUGENE F., Editor, *Metallurgical and Chemical Engineering*, New York; res., 29 Halsted St., East Orange, N.J.

TEELE, FRED WARREN, President and General Manager, Porto Rico Railway, Light & Power Co., San Juan, P.R.

WILLIAMS, WILLIAM J., Power Engineer and Chief Electrical Assistant, Electricity Dept., Municipal Council of Shanghai, China.

Associates Elected June 25, 1914

ADAMS, OSMOND FENWICK, Demonstrator in Electrical Engineering, University of Toronto; res., 132 Ulster St., Toronto Ontario.

ALBRIGHT, ARTHUR S., Engineer, Meter Dept., Edison Illuminating Co. of Detroit; res., 109 Taylor Ave., Detroit, Mich.

ANDREWS, SAMUEL W., Portland, Eugene & Eastern Railway Co., 305 Beck Bldg., Portland, Ore.

BELL, ANDREW L., Mechanical Engineer, Isthmian Canal Commission, Culebra, C. Z.

BENZING, HARRY J., Cadet Engineer, Counties Gas & Electric Co., Wayne; res., 716 W. Allegheny Ave., Philadelphia, Pa.

Boyd, Alfred Peck, Newark, N. J.

Brandes, William P., Cashier. H. S. Kerbaugh, Inc., Magnolia, Morgan Co., W. Va.

Brightbill, Floyd G., Power Department, West Penn Railways Co.; res., 208 E. Fairview Ave., Connellsville, Pa.

Broili, Frank O., Consulting and Contracting Engineer, 121 North St., Virginia City, Va.

Brown, Ernest Wilcox, Sales Representative, Allis-Chalmers Mfg. Co., 814 Frick Bldg., Pittsburgh, Pa.

Brunet, Robert Leonard, Public Service Engineer, City Hall, Providence, R.I.

Bullock, Oliver, Electrical Foreman, Isthmian Canal Commission, Miraflores Locks; res., Pedro Miguel, C.Z.

Caley, Russell D., Wireman, Isthmian Canal Commission, Miraflores; res., Corozal, C.Z.

Carlson, Alexander U., Commercial Dept., Washington Water Power Co.; res., S 613 Sheridan St., Spokane, Wash.

Carron, Harold G., Salesman, Electric Storage Battery Co. of Philadelphia, 722 Ford Bldg., Detroit, Mich.

Chamberlin, Guy N., Engineer, Arc Lighting Dept., General Electric Co., Lynn, Mass.

Charley, Reginald Morse, Electrical Engineer, Westinghouse Electric & Mfg. Co., E. Pittsburgh; res., Westinghouse Club, Wilkinsburg, Pa.

Coates, William A., Chief Engineer, Ferranti Electrical Co. of Canada, Ltd., Toronto, Ontario.

Cook, Charles G., Station Operator, Pearsons Engineering Corp., 115 Broadway, New York, N.Y.

Cooley, Edward H., Instructor, Bliss Electrical School; res., 118 N.Y. Ave., Takoma Park, Washington, D.C.

Crothers, Harold M., Instructor, University of Wisconsin, Madison, Wis.

Davidson, Ward F Special Graduate Student, University of Michigan, Ann Arbor; res., Iron Mountain, Mich.

Dawson, William E., Assistant Meter Foreman, Portland Railway, Light & Power Co.; res., 5020 42nd St. S. E., Portland, Ore.

Dean, P. P., Electrical Engineer, Diehl Mfg. Co., 90 Prince St., New York, N.Y.

de Boeck, Francis, Assistant Engineer, Bowness Improvement Co.; res., 1335 11th Ave. West, Calgary, Alta.

de Laval, C. G. Hjalmar, Electrical Engineer, General Electric Co.; res., 7A Shore Drive, Lynn, Mass.

Dickson, Walter S., Electrical Engineer, Chile Exploration Co., New York; res., N. Midland Ave., Arlington, N.J.

Dinion, Nathan, Engineering Dept., Acme Wire Co.; res., 743 State St., New Haven, Conn.

Eckley, George M., Electrical Engineer, Westinghouse Electric & Mfg. Co., E. Pittsburgh; res., Clover Club, Edgewood Park, Pittsburgh, Pa.

Eddington, Alfred, Electrical Engineer, Marconi's Wireless Telegraph Co. Ltd.; res., 100 Mildmay Rd., Chelmsford, England.

Enloe, Eugene. President, Okonogan Valley Power Co., 521- 1st Ave., Spokane, Wash.

Ferrier, Tyrrell, Factory Inspector, Hydro-Electric Power Commission of Ontario, Toronto, Ontario.

Flanders, Milton M., Charge of Testing Dept., Bliss Electrical School; res., 31 Maple St., Takoma Park, Washington D.C.

Fletcher, James Young, Manager, Incandescent Lamp & Illuminating Engineering Dept., General Electric Co., 67 Queen Victoria St., London, England.

Grimsdick, Edward P., Indian Representative, General Electric Co., Calcutta, India.

Hall, Frederic Sampson, Transformer Dept., General Electric Co., Lynn; res., 12 Maple Ave., Swampscott, Mass.

HARRINGTON, CLINTON O., JR., Engineer, Union Switch & Signal Co., Swissvale; res., 147 Lloyd Ave., Edgewood Park, Pittsburgh, Pa.

HEGERTY, PERRY F., Salesman, Westinghouse Machine Co., 500 Westinghouse Bldg., Pittsburgh, Pa.

HENDRICKSON, George F., General Foreman, Colorado Springs Light, Heat & Power Co.; res., 323 S. Cascade Ave., Colorado Springs, Colo.

HOLSEY, T. E., Commercial Dept., Washington Water Power Co.; res., E. 2018 11th Ave., Spokane, Wash.

HORN, ALAN R., Electrical Engineer, Office of the Supervising Architect, Treasury Department; res., 29 W St. N. W., Washington, D.C.

ILSLEY, LEE C., Assistant Electrical Engineer, United States Bureau of Mines; res., 7447 Monticello St., Pittsburgh, Pa.

JEFFERIES, ERNEST S., Electrical Engineer, Steel Company of Canada; res., 209 James St. South, Hamilton, Ont.

JOHNSON, CARL W., Salesman, Westinghouse Electric & Mfg. Co., 1205 Dime Savings Bank Bldg., Detroit, Mich.

JOHNSON, OTTO H., Telephone Engineer, Tri-State Telephone & Telegraph Co.; res., 1996 Milwaukee Ave., St. Paul, Minn.

JOHNSTONE, DOUGLAS MCNOUGHT Asst. Electrical Supt., British Columbia Electric Railway Co.; res., 2735 Sophia St., Vancouver, B.C.

KALLEVANG, EDWIN J., Foreman of Construction and Maintenance, DeKalb-Sycamore Int. Traction Co. and De Kalb-Sycamore Electric Co.; res., 141 Park Ave., De Kalb, Ill.

KELLER, LOGAN HERBERT, Manager Chicago Office, Maloney Electric Co., 1716 Fisher Bldg., Chicago, Ill.

KERSEY, GLEN B., Electrical Designer, Commonwealth Edison Co., 28 N. Market St., Chicago, Ill.

KOCH, RICHARD, General Manager, Concordia Safety Lamp Co.; res., 5524 Baywood St., Pittsburgh, Pa.

KOSTKO, JAROSLAW K., Electrical Engineer, Wagner Electric Mfg. Co., 6400 Plymouth Ave., St. Louis, Mo.

LEHMPUHL, HERMANN F., Testing Engineer, Public Service Co. of Northern Illinois; res., 3811 N. Seeley Ave., Chicago, Ill.

LIDBURY, FRANK AUSTIN, Works Manager, Oldbury Electro Chemical Co., Niagara Falls, N.Y.

MACTAVISH HERBERT JAMES, Sales Engineer, Canadian General Electric Co., Toronto, Ont.

MALOTT, CARL G., Student, Purdue University; res., 427 State St., West Lafayette, Ind.

MARSHALL, ALFRED C., Vice-President, Detroit Edison Co.; res., 105 Calvert Ave., Detroit, Mich.

MARSHICK, OLIVER J., Electrician, Edison Illuminating Co.; res., 7 Park Ave., Detroit, Mich.

MCCLURE, LAURENCE HUTCHINSON, Assistant to Superintendent of Distribution, Hartford Electric Light Co.; res., 31 Deerfield Ave., Hartford, Conn.

MCELROY, ROSS BERNARD, Commercial Dept., Washington Water Power Co., Spokane, Wash.

MELVIN, CHARLES EUGENE, First Class Electrician, United States Navy, U. S. S. *Severn*, New York, N.Y.

MERTENS, BERNARD DE M., Electrical Engineer, British Columbia Electric Railway Co.; res., 2239 15th Ave. W., Vancouver, B.C.

MILLER, CLAYTON A., Student in Electrical Engineering, University of Illinois, Urbana, Ill.

MOY, FRANK, 1st Assistant Inspector, Bureau of Gas, Room 332, City Hall, Philadelphia, Pa.

MORRISSEY, JOHN P., Assistant Engineer, Pattison Brothers; res., 6 Henderson Place, New York, N.Y.

MORT, WILLIAM, Mechanical Engineer, Singer Manufacturing Co., 149 Broadway, New York, N.Y.

NORDWALD, B., Station Operator, Los Angeles Railway Co.; res., 1001 W. 8th St., Los Angeles, Calif.

NYMAN, HJALMAR EDWARD, Draftsman and Inspector, Power Dept., Detroit United Railway, Detroit, Mich.

OUTZEN, ANDREW N., Engineering Dept., Madison Gas and Electric Co., 122 E. Main St., Madison, Wis.

PAINE, ROY McG., System Load Dispatcher, British Columbia Electric Ry. Co., Main St. Substation, Vancouver, B.C.

PAYNE, THOMAS H., Engineering Dept., West Texas Electric Co., Sweetwater; res., 303 Clay St., Ft. Worth, Texas.

PERNOT, FRED EUGENE, Instructor in Electrical Engineering, University of California, Mechanical Building, Berkeley, Cal.

RAMSAY, ALEXANDER T., Engineering Dept., Southern Bell Tel. & Tel. Co., 57½ S. Pryor St., Atlanta, Ga.

RATHBUN, BYRL C., Chief Electrician & Electrical Engineer, Standard Chemical Co.; res., 122 Elm St., Cannonsburg, Pa.

RICE, CHESTER W., Consulting Engineering Dept., General Electric Co.; res., Lenox Road, Schenectady, N.Y.

RICHARDS, WILLIAM E., Supt. of Electric Dept., Toledo Railways & Light Co.; res., 422 Victoria Place, Toledo, Ohio.

RIDDICK, ARCHIE G., Student, University of Alabama, Gurley, Ala.

ROBBINS, THOMAS W., Station Operator, Utah Power & Light Co., Olmstead, Utah.

ROHR, CHARLES A., Small Motor Specialist, General Electric Co., 30 Church St.; res., 65 W. 71st St., New York, N.Y.

RUSSELL, BEN C., Idaho Railway, Light & Power Co., Boise; res., Weiser, Idaho.

SAMPLE, RALPH MARSHALL, Engineering, Automatic Telephone, Western Electric Co.; res., 215 W. 45th St., New York, N.Y.

SARA, RICHARD ALLAN, Sales Manager, City Light and Power Department; res., 301 Balmoral St., Winnipeg, Man.

SCHOU, THEODORE, Chief Engineer, Electric Machinery Co., Minneapolis, Minn.

SCHROEDER, JOHN H., Instructor in Electrical Engineering, Georgia School of Technology, Atlanta, Ga.

SCHWARZ, FREDERIC J., Electrical Engineer, General Electric Co., Schenectady, N.Y.

SCOVEL, HARLEY W., Draughtsman, Commonwealth Edison Co., 28 N. Market St., Chicago, Ill.

SELLECK, ROYAL R., Electrical Engineer, J. G. Frazier Co.; res., 872 Parkwood Drive, Cleveland Ohio.

SHANNON, JOHN F., Chief Engineer, Beardsley Electric Co.; res., 2649 Brighton Ave., Los Angeles, Cal.

SHARP, JOHN MCREYNOLDS, Instructor, Bliss Electrical School, Takoma Park, D. C.

SINCLAIR, ROSCOE, Switchboard Operator, Pacific Light & Power Corp., Redondo Beach, Cal.

SMITH, VERNON L., Central Station Operator, Los Angeles Railway Corp.; res., 886 E. 38th St., Los Angeles, Cal.

THAU, WALTER E., Electrical Engineer, Westinghouse Electric & Mfg. Co., E. Pittsburgh; res., 539 Jeannette St., Wilkinsburg, Pa.

THOMPSON, LOUIS WILLARD, Electrical Engineer, Thompson-MacArthur Regulator Co. and Thompson-MacArthur Inspection Co., 70 West Chippewa St., Buffalo, N.Y.

TUCKER, FRED A., Electrical Engineer, Cutler-Hammer Mfg. Co.; res., 183 14th St., Milwaukee, Wis.

WEBSTER, ROBERT ALDEN, Electrical Draftsman, U. S. Coast Defense Service, Washington Barracks, D.C.

WEBSTER, SAMUEL T., Motor and Generator Designer, Wagner Electric Co., 6400 Plymouth Ave., St. Louis, Mo.

WESTERVELT, HAROLD POPE, Test Dept., New York Edison Co., 92 Vandam St., New York, N.Y.

WILBER, SHEPARD B., Electrical Contractor, 8 Norwich St., Worcester, Mass.

WILLIS, A. HUNTER, Electrical Engineer, Burke Electric Co., Erie, Pa.
WILSON, LAWRENCE A., Engineering Dept., Electric Distribution, Pacific Gas & Electric Co., Berkeley; res., 322 Howard Ave., Oakland, Cal.
WORK, LEONARD, Foreman Electrical Construction, Isthmian Canal Commission, Pedro Miguel, C.Z.
Total 100.

Applications for Election

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before July 30, 1914.

Adler, L., Corozal, C. Z.
Beck, O. C., Baltimore, Md.
Bernhard, J. H., New Orleans, La.
Bishop, R. Pedro Miguel, C. Z.
Cahse, S. R., Altoona, Pa.
Clark, B. W., Detroit, Mich.
Coyle, F. B., Ancon, C. Z.
Dean, G. R., Rolla, Mo.
Downing, J. W., Salesbury, Md.
Endress, W. F., Gatun, C. Z.
Gardner, H. S., Chicago, Ill.
Gray, H. L. (Member), Seattle, Wash.
Gross, B., New York, N. Y.
Henk, P. V., Sydney, N. S. W.
Hering, C. P. (Member), Manila, P. I.
Herzsch, F. H., Cincinnati, O.
Horle, A. M., Cristobal, C. Z.
Hunt, N. H., Texas City, Tex.
Izhuroff, B. A., St. Petersburg, Russia.
Lindstrom, A. S., San Francisco, Cal.
Maluquer i Nicolau, J., Barcelona, Spain
Manning, J. H. (Member), Boston, Mass.
Medeiros, A. de B., Brooklyn, N. Y.
Moore, A. H., (Member), Albany, N. Y.
Newton, A. H., Cleveland, O.
Pearce, W. C., Syracuse, N. Y.
Pontecorvo, G., E. Pittsburgh, Pa.
Pritchard, H. T., Chicago, Ill.
Remer, G. D., Dows, Iowa.
Rider, O. O. (Member), Chicago, Ill.
Roberts, C. W., Gatun, C. Z.
Roberts, G. R. W., Portland, Ore.
Saunders, J. E., Pittsburgh, Pa.
Schuake, E. W., Corozal, C. Z.
Schutt, G. H., Pedro Miguel, C. Z.
Seaver, H., Corozal, C. Z.
Shipley, G. A., Los Angles, Cal.
Steiner, C. W., St. Louis, Mo.
Stephens, W. H., Portland, Ore.
Swift, F. H., Powell River, B. C.
Thompson, J. S., San Francisco, Cal.
Thomson, A., Invercargill, N. Z.
Thrall, C. H., Havana, Cuba
Vaniman, R. L., Vancouver, B. C.
Williams, J. F., Chuquicamata, Chili
Wright, J. D., Schenectady, N. Y.

Students Enrolled June 25, 1914

6610 Schadt, E. K., A. & M. Coll. of Texas.
6611 Yeager, L. R., Ohio State Univ.
6612 Lankton, W.W., Mich.St.Agri.Col.
6613 Houston, M., Univ. of Wisconsin.
6614 Kranz, H. E., Univ. of Wisconsin.
6615 Warwick, G. F., Ga. Sch. Tech.
6616 Horner, O. H., Univ. of Kansas.
6617 Ellms, C. W., Tufts College.
6618 Harless, F. E., Ga. Sch. Tech.
6619 Mailhouse, R. J., Yale Univ.
6620 French, J. A., Tufts College.
6621 Little, C. B., Univ. of Wisconsin.
6622 Templeton, F. H., Univ. of Mo.
6623 Kossif, N., Univ. of Pennsylvania.
6624 Judge, J. A., Mass. Inst. Tech.
6625 Johnson, G., Univ. of Wisconsin.
6626 Skinner, D. C., W. Va. Univ.
6627 Phelps, H.E., Worcester Poly.Inst.
6628 Sellers, S. R., Pa. St. Coll.
6629 Ordonez, B. R., Univ. of Ill.
6630 Barnwell, G.W., Mass.Inst.of Tech.
6631 Murphy, R.J., Mass. Inst. of Tech.
6632 Spicer, W.E., Worcester Poly.Inst.
6633 Shackleton, S. P., Univ. of Mich.
6634 Wentworth, H. H., Worcester Polytechnic Institute
6635 Titshaw, E. P., Ga. Sch. Tech.
6636 Blodget, H. Y., Cornell Univ.
6637 Stack, A. H., Cornell Univ.

6638 Yang, S. Z., Worcester Poly. Inst.
6639 Shoemaker, F. G., Univ. of Ill.
6640 Suter, E. R., Univ. of Illinois
6641 Pauly, H. C., Univ. of Kansas.
6642 Weibling, M. M., Ohio St. Univ.
6643 Parks, J. B., Lehigh University
6644 Hall, O. C., Mass. Inst. Tech.
6645 Tickle, R. F., Univ. of Mo.
6646 Enos, H. A., Univ of Michigan.
6647 Vogel, H. F., Lehigh.Univ.
6648 Fisher, S., Columbia Univ.
6649 Baldwin, H.D., Lehigh Univ.
6650 Macon, L. D., Univ of Missouri.
6651 Hoffman, L. C., Univ. of Wis.
6652 Replinger, R. L., Univ. of Wis.
6653 Tolhurst, W. H., Univ. of Wis.
6654 Smith, G. T., Mich. Agri. Coll.
6655 Mayer, H. A., Mass. Inst. Tech.
6656 Gauthier, W. B. J., Pa. St. Coll.
6657 Carpenter, J. W., Pa. St. Coll.
6658 Whitaker, J. R., Univ. of Pa.
6659 Fourness, C. A., Univ. of Wis.
6660 Laue, G. E., Univ, of Wis.
6661 Crichfield, G., Stevens Inst.
6662 Babb, H. S., Ore. Agri. Coll.
6663 Phelps, F. E., Mich. Agri. Coll.
6664 Leonard,S.G.,WorcesterPoly.Inst.
6665 Albers, H. H., Stevens Inst.
6666 Clickner, J. E., Univ. of Mich.
6667 Davis, A. F., Ohio St. Univ.
6668 West, H., Univ of Illinois.
6669 Ferguson, G. F., Worcester Polytechnic Institute.
6670 Barron, T. H., Ga. Sch. Tech.
6671 Cone, M. S., Ga. Sch. Tech.
6672 Kilby, H. S., Univ. of Ill.
6673 Nelson,G.W.,Worcester Poly.Inst.
6674 Mathews, H., Univ. of Illinois.
6675 Hart, P. M., Univ. of Illinois.
6676 Dendel, L. P., Mich, Agri. Coll.
6677 Bowen, H., Univ of Wash.
6678 Pye, J. W., Ga. Sch. Tech.
6679 Fisher, R. S., Drexel Inst.
6680 Delp, L. A., Drexel Inst.
6681 Funk, R. J., Drexel Inst.
6682 Marklewitz, E.A., Mich.Agri.Coll.
6683 Meisekothen, R. J., Univ. of Wis.
6684 Thomas, E. F., Univ. of Wis.
6685 Huyck, A.B.,Rensselaer Poly.Inst.
6686 Conklin,S.H.,RensselaerPoly.Inst.
6687 Crandell,E.D.,RensselaerPoly.Inst

Past Section Meetings

Baltimore.—May 15, 1914, Physical Laboratory, Johns Hopkins University. Paper; "Illumination", by W. U. Nodel. Officers for ensuing year were elected as follows: chairman, J. B. Whitehead; secretary and treasurer, L. M. Potts; executive committee, Messrs. J. B. Whitehead, L. M. Potts, A. S. Loizeaux, A. T. Clark, W. H. Swift, R. C. Faught, H. B. Stabler, F. A. Allner, and C. G. Edwards. Attendance 12.

Boston.—May 21, 1914, Engineers Club. Subject; Transmission. Paper; "The Operation of a Transmission System," by T. A. Lees. Officers for the ensuing year were elected as follows: chairman, Harold Pender; vice-chairman, George W. Palmer, Jr., secretary and treasurer, Harry F. Thomson; executive committee, Charles T. Mosman, W. Irving Middleton, and George A. Burnham. Attendance 53.

Cleveland.—May 25, 1914, University Club. Address was given by President-elect P. M. Lincoln on "Co-operation." Attendance 34.

Detroit-Ann Arbor.—May 8, 1914, Eastern Michigan Edison Company Building, Ann Arbor. Subject; Kilowatt-Hour. Paper; "Factors Entering into the Cost of a Kilowatt-Hour", by H. L. Wallau. Attendance 165.

Los Angeles.—May 26, 1914, University of Southern California. Address by Professor A. W. Nye on "Some Features of Teaching Electrical Engineering." Attendance 56.

Lynn.—May 21, 1914, General Electric Works, Old Office Building. Illustrated lecture by Mr. Fred M. Kimball on "Mexico." Election of officers for the ensuing year as follows: chairman, W H. Pratt; secretary-treasurer, F. S. Hall; executive committee, Messrs. G. N. Chamberlin, A. H. Burritt, F. J. Rudd, C. H. Stevens, E. R. Berry. Attendance 299.

Madison.—April 2, 1914, Madison City Library. Subject; State Regulation. Paper; "A Comparison of Statutory Regulation of Public Utilities

in the Various States," by R. C. Disque. Attendance 22.

June 4, 1914, Madison. Election of officers for ensuing year as follows: chairman, J. W. Shuster; secretary-treasurer, F. A. Kartak; executive committee, J.W. Shuster, F. A. Kartak, and C. M. Jansky. Attendance 7.

Mi waukee.—May 13, 1914, Colonial Room, Plankinton House. Paper; "Conveying and Hoisting Machinery," by C. Kemble Baldwin. Joint meeting with Engineers Society of Milwaukee. Attendance 140.

Minnesota.—May 25, 1914, Ryan Hotel, St. Paul. Papers; "A Comparison of the Telegraph with the Telephone as a Means of Communication in Steam Railroad Systems," by M. H. Clapp, "Some Central Station and High-Tension Transmission Statistics," by W. T. Ryan. Election of officers for ensuing year as follows: chairman, Leo H. Cooper; secretary-treasurer, Emil Anderson; third member of executive committee, R. A. Lundquist. Attendance 40.

Panama.—May 6, 1914, Balboa, Canal Zone. Paper; "Power and Illumination System at Balboa Shops," by Hartley Rowe. Inspection trip through government shops. Re-election of present officers for ensuing year. Attendance 71.

Philadelphia.—June 8, 1914, Colonnade Hotel. Annual meeting, also 100th meeting of Philadelphia Section. Election of officers for the ensuing year as follows: chariman, H. F. Sanville; managers, C. W. Sharer, W. C. Kerr, Hugh Leslie; secretary and treasurer, W. F. James; assistant secretary, Charles Penrose. Short addresses were given by President C. O. Mailloux, President-elect P. M. Lincoln, and Messrs. Ralph W. Pope, Farley Osgood, Clayton W. Pike, W. C. L. Eglin and H. F. Sanville. Attendance 123.

Pittsburgh.—May 12, 1914, Oliver Building. Professor Vladimir Karapetoff gave a lecture on "Preparation and Qualifications of a Teacher of Engineering." Attendance 70.

Portland.—May 5, 1914, Assembly Hall. Illustrated lecture delivered by Mr. F. W. Hild on "Some of the Economic Problems of the Public Utility." Attendance 35.

San Francisco.—April 23, 1914, Engineers Club. Subject; Telephony. Paper; "Some Features of Construction and Operation of Telephone Plants," by D. P. Fullerton. Attendance 55.

May 22, 1914, Engineers Club. Paper "Resume of Diesel Motor Installations, by L. R. Jorgensen. Attendance 55.

Schenectady.—May 20, 1914, Edison Club Hall. Illustrated lecture by Dr. E. B. Rosa on "Electrolysis and Its Mitigation." Attendance 200.

Seattle.—May 19, 1914, Men's Club, University of Washington. Subject; Electrolysis. Paper; "Electrolysis in Reinforced Concrete," by C. E. Magnusson. Attendance 36.

Spokane.—April 17, 1914, Silver Grill. Subject; Telephony. Papers; "The Automatic Telephone" by E. L. Burbridge, and "Building up the Commercial Load" by I. A. Shorno. Attendance 55.

Toledo.—June 3, 1914, Toledo Commerce Club. Lectures by Messrs. Grah and Ross on "The Present and Future Electrical Developments of the Toledo Railways and Light Company," illustrated by lantern slides. Attendance 18.

Urbana.—May 29, 1914, Electrical Engineering Laboratory. Paper; "Direct-Current Corona," by S. P. Farwell. Election of officers for ensuing year as follows: chairman, L.W. Fisk; secretary-treasurer, P. S. Biegler. Attendance 40.

Washington.—May 20, 1914, Telephone Building. Exhibition of moving pictures of the Panama Canal. Election of officers as follows: chairman, C. B. Mirick; secretary, C. A. Peterson. Attendance 48.

Past Branch Meetings

University of Cincinnati.—April 1, 1914, Cincinnati. Election of officers. The following new officers were elected: chairman, M. L. Harned; 1st vice-chairman, F. Oberschmidt; 2nd vice-chairman, R. H. Kruse; secretary, A. C. Perry.

University of Colorado.—May 13, 1914, Boulder, Colo. Illustrated lecture by Mr. W. F. Cozad on "Modern Telephone Industry." Election of officers for the coming year as follows: president, Philip S. Borden; vice-president, Thornton Victory; secretary, Charles Miller; treasurer, Maurice W. Shugren; junior representative, Victor E. Flanagan. Attendance 35.

Colorado State College.—May 27, 1914, Electrical Engineering Building. Stereopticon lecture by Prof. Rankin. Attendance 39.

Lafayette College.—May 18, 1914, Pardee Building. Papers; (1) "Ice Making as a Side Industry of a Power Plant," by P. M. Lee; (2) "Steam Heating as a By-Product of Power Plants," by R. M. McMonigal; (3) "Thesis," by Ellis. Attendance 22.

May 27. Papers; (1) "The Firefly as a Light Source" by L. R. Lefferson; (2) "Types of Quartz Light," by W. J. English, Jr. (3) "The Development of Electricity for Heating and Cooking," by W. H. Powell. Attendance 19.

May 28, 1914. Papers; (1) "The Problem of Electrification of Trunk Lines," by L. Van Inwegen; (2) "The Booster System on Trolley Lines," by R. Soles; (3) "Color Blindness, Its Causes and Effects," by J. H. Kennedy. Attendance 19.

June 1, 1914. Papers; (1) "Electric Railway Automatic Block Signaling," by R. Lohman; (2) "High-Tension Insulators," by W. B. Killough; (3) "Generator for Wireless Relays," by J. H. Kerrick. Attendance 19.

Lehigh University.—May 15, 1914, Physical Laboratory. Papers; (1) "Electric Vehicles," by J. S. Williamson; (2) "Analogies between Electrical Circuits and Simple Mechanics," by Prof. W. S. Franklin. The following officers were elected: president, N. F. Matheson vice-president, E. R. Frey; secretary, F. C. Brockman; treasurer, O. W. Eshbach; faculty advisor, W. S. Franklin. Attendance 45.

Lewis Institute.—April 29, 1914, Lewis Institute. Illustrated lecture by Mr. William A. Durgin, "From Lightning to Lighting." Attendance 300.

University of Missouri.—May 21, 1914, engineering Building. The following addresses were given (1) "Pole Preservation," by L. L. Crump; (2) "Line Construction," by E. V. Gmeiner. Officers for the coming year were elected as follows: chairman, E. W. Kellogg; vice-chairman, G. F. Schultze; secretary, K. Atkinson; assistant secretary, D. S. Foster; corresponding secretary, C. M. Duren; treasurer, L. R. Galladay. Attendance 18.

Ohio Northern University.—May 6, 1914, Ada, Ohio. Papers; (1) "Friday of the Inspection Tour in Chicago," by L. A. Peck; (2) "Wednesday of the Inspection Tour in Chicago," by G. H. Bull. Officers for the coming year were elected as follows: chairman, A. B. Curtis; vice-chairman, R. E. Lowe; secretary, W. F. Schott; treasurer, L. L. Daubenspeck; executive committee, H. M. Downing, H. R. Smith, L. W. Brehman, and W. L. Riggin. Attendance 17.

Ohio State University.—May 15, 1914, Robinson Laboratory. Discussion of Branch matters. Attendance 25.

Purdue University.—May 19, 1914, Electric Building. Election of officers for the coming year, as follows: chairman, L. W. Spray; secretary, R. E. Tafel; treasurer, E. O. Malott. Attendance 54.

Rhode Island State College.—May 6, 1914. Science Hall. Address by Mr. Henry M. Brightman on "The Process of Drying," illustrated with lantern slides. Election of officers as follows: chairman, W. C. Miller; vice-chairman, P. A. Kivilin; treasurer, L. H. Mailloux;

secretary, P. M. Randall, Jr. Attendance 47.

University of Washington.—May 5, 1914. Paper; "Transmission Operation," by M. T. Crawford. The following officers were elected: chairman, H. W. McRobbie; secretary, B. B. Bessesen executive committee, H. W. McRobbie, B. B. Bessesen, and L. F. Curtis. Attendance 30.

Yale University.—May 15, 1914, New Haven, Conn. The following addresses were given (1) "Corporations," by A. J. Campbell; (2) "General Distribution and Load Factor," by A. D. Colvin; (3) "Sales Work in Central Stations," by B. H. Gardener; (4) "Growth of Central Station Work," by C. E. Clewell. Officers for the ensuing year were elected as follows: chairman, F. M. Doolittle; secretary, W. L. Kenly; treasurer, W. B. Kirk; executive committee, K. Y. Mok, D. Cooksey, and Prof. C. F. Scott. Attendance 75.

Personal

MR. GERARD SWOPE, vice-president and general sales manager of the Western Electric Company, sailed for Europe on June 6 on a two months' business trip, in the course of which he will visit the company's various allied interests abroad.

PROFESSOR HAROLD PENDER of Boston has accepted the position of professor of electrical engineering at the University of Pennsylvania in Philadelphia, and will have complete charge of that department, which has recently been made a separate and independent department.

MR. J. S. S. COOPER has resigned his position as chief engineer to Messrs. Samuel and Company, Ltd., Shanghai, to enter the service of Messrs. Arnhold, Karberg and Company as special representative engineer. Mr. Cooper's headquarters will be in Shanghai, but his duties will probably take him into other parts of China for a considerable portion of the time.

MR. CHARLES E. SCRIBNER, chief engineer of the Western Electric Company, recently returned to New York after a visit of two months to Europe. Mr. Scribner appeared in London before a Parliamentary Commission to present data regarding the new long-distance, high-speed printing telegraph developed under his supervision. A trial installation is to be made in England.

MR. R. L. VANIMAN, formerly associated as consulting engineer with Starrett and Van Vleck, has been appointed associate engineer and Western representative of P. R. Moses, 366 Fifth Avenue, New York, and his office will be in Vancouver, B. C. Mr. Vaniman has just completed for Mr. Ashley, consulting engineer for Starrett and Van Vleck, the complete engineering equipment of the new Lord and Taylor store in New York.

MR. JAMES T. BOUSTEAD, of Minneapolis, Minn., who recently resigned the presidency of the Electric Machinery Company, of which he was the founder 23 years ago has organized the Boustead Electric and Manufacturing Company, with offices, salesroom and shop at 215 First Avenue, North, Minneapolis. The new firm will manufacture switchboards and panel boards, and motors up to 50 h.p., and will handle a complete line of generators and electrical machinery.

Obituary

JOSEPH ADDISON SANDFORD, JR., died at the City Hospital, East Liverpool, Ohio, on May 21, 1914. He had been operated upon for appendicitis the previous day, after a brief illness.

Mr. Sandford was born at Ware, Mass., October 17, 1879. His early education was obtained in the Ware public schools, after which he attended the Highland Military Academy at

Worcester for four years. He then entered the Worcester Polytechnic Institute, from which he was graduated with the degree of B. S. in 1903. After a year as electrical engineer of the New Lexington High-Voltage Porcelain Company of New Lexington, Ohio, he returned to Worcester Polytechnic Institute and received the degree of E. E. in 1905. For the next two years he was with the C. S. Knowles Company of Boston. He then entered the employ of the R. Thomas and Sons Company, being attached to the New York office unti 1909, when he was appointed electrical engineer of the company, with headquarters at East Liverpool. This latter position he held to the time to his death.

Mr. Sandford was married November 30, 1910, to Ethel Smith of Ware, Mass. He is survived by Mrs. Sandford and a two-year old son, Addison Lawton Sandford.

Mr. Sandford was elected an Associate of the Institute on October 9, 1908, and was transferred to the grade of Member on March 14, 1913.

Abstracts of Proceedings of Foreign Engineering Societies

ELEKTROTECHNISCHER VEREIN

Lecture of Prof. Dr. A. Korn before the Elektrotechnischer Verein, February 17, 1914, on the subject of "The Present State of Telewriting," with special reference to a new step-by-step relay for reinforcing the currents which were up to the present furnished by the selenium method.

The lecturer first gave a review of the work he had done in long-distance transmission of photographs and pictures, calling to mind that he had lectured on the same subject nine years ago before the Verein. We differentiate between two methods of transmission: the selenium method and the telautographic method. The selenium method is based on the sensitiveness to light on the part of selenium, in which the selenium changes its electrical resistance with the change of light. A photograph in the form of a transparent film is wound on a glass cylinder and the light of a Nernst lamp is concentrated on one point in the photograph with the aid of a good lens. The light passes through the film and the glass cylinder and is then thrown on a selenium cell, which thus receives more or less light, depending on the transparency of the elements of the photograph struck by the pencil of light. If we pass the current of a constant battery through the selenium cell finally reaching a receiving station at some distant point, the intensity of the incoming current will correspond to the shadings of tones of the photograph in question. The transmitting cylinder is set uniform rotation, and at every revolution moves slightly in the direction of the cylinder axis, so that the detailed elements of the original photograph, detail by detail, line by line, are touched and with the help of the currents reaching the receiving station. the picture is composed again in the receiver in form of a photograph. The disadvantage of the selenium method lies in the weakness of the line currents, which are at most a milliampere. Consequently disturbances on neighboring lines have a great influence on the transmission.

The telautographic method of transmission of pictures, which has been known for about 70 years, is based on the following principle: The drawing is transferred to a metal foil by means of an "ink" which does not conduct electricity, and this foil is wound around a rotating cylinder. While the cylinder is in rotation, a fine metal point is in contact with it. This metal point, similar to the needle in a phonograph, moves with each cylinder rotation slightly in the direction of the cylinder axis. Thus the metal point touches every point in the entire foil, moving in a direction similar to a fine screw thread, and every time that the point reaches a conducting spot in the foil, a current is trans-

mitted to the distant receiving station, while on the other hand the current is interrupted when the metal point is on a non-conducting part of the foil, *i e.*, on a section of the picture or writing. With the aid of current impulses reaching the receiving station, the picture can be reproduced in the receiver. In the earlier tests of Bain, Bakewell, Caselli, etc., this process went on too slowly to allow practical application. Through the introduction of a suspension galvanometer into the receiving instruments, by Korn, and through the method of photographic registration, the speed of transmission has become so great that this method is now practically applicable, not only for the transmission of drawings and writing, but also for the transmission of photographs which have been previously changed into black and white pictures through a notching process (auto type). Within the last few years detailed pictures have been transferred with great success between Berlin and Paris, Paris and Monte Carlo, Paris and London, London and Manchester, indeed even between Berlin and Monte Carlo. The results have been far more successful than those obtained with the selenium system. The telautographic method can work with stronger currents, 10 to 20 milliamperes, which is one reason why it has been preferred within recent times to the selenium method.

The telautographic method has a disadvantage, though, in that a considerable number of signs per second must be sent over the wires in order to obtain sufficient speed of transmission. For this reason it is not applicable for transmission on long lengths of cable. The lecturer therefore took up the original problem again to make the selenium method practical by reinforcing the transmission currents. The solutions found for this purpose furnished the principal element in his lecture. In this new process the weak currents obtained from the selenium method are not sent directly in to the line but first into a peculiar relay. The latter consists of a sensitive moving-coil galvanometer, whose needle plays over a contact field, without, however, touching the same. The contact field and the needle are connected to an apparatus for production of high-frequency currents, and the arrangement is such that the high-frequency currents pass from the needle of the instrument to the contact in the contact field corresponding to the position of the galvanometer needle, and are then transmitted by this contact to a special spark gap lying outside of the instrument. To each spark gap a parallel voltage is connected, which generates a high-tension current arc at the spark gap, but only when the weak Tesla sparks appear. Consequently in every position of the galvanometer needle, corresponding to every tone of the picture, we have only one certain arc, a definite high-tension current circuit is closed, and with these high-tension currents we can do whatever we please. We can either send a portion of these high-tension currents into the wires, or else, better than that, these currents may be used to furnish a perforated strip, which then represents the picture and by means of which the picture can now be transmitted with the required speed of transmission over the wires. Finally, it would be possible with the help of the high-tension currents accompanying these tones to produce letter telegrams which are transmitted like regular telegrams and are used at the receiving station to reproduce the picture.

Meeting of March 10, 1914

Paper of Professor Breisig, on Long-Distance Telephone Cables, Especially the Berlin-Cologne Line.

The superiority of cable telephone lines over over-head lines consists especially in the former not being subject to atmospheric influences nor to high-potential currents flowing in the neighborhood. On the other hand, troubles arise owing to the high capacity of the

cables, which causes a considerable damping of the telephone currents; this may be, however, to a large extent eliminated by Pupin loading coils. The use of Pupin coils, however, increases the total resistance of the line, and this limits the use of cable telephony to certain definite distances. The speaker showed in detail the method of calculation of the constants of damping, and indicated the limits within which one can still obtain a good hearing. He passed then to the long-distance cable line now being laid by the Royal Post Office between Berlin and Cologne, and to the section between Berlin and Magdeburg already constructed. Hitherto long telephone cable lines have been laid only in exceptional cases (in America) and, in view of the high cost of the work, all details had to be handled with the utmost care. The speaker described the calculation and construction of the cable line, and presented the results of tests undertaken previous to the final design.

Paper by Dr. Ebeling: Experiences in Manufacturing and Laying the Berlin-Magdeburg Cable.

The speaker described in great detail and illustrated by numerous slides the laying of the telephone cable from Berlin to Magdeburg. Thus, the unloading of the heavy coils and their transportation from the railroad station to the place of laying involved considerable difficulties, which were overcome by the use of a powerful automobile truck. The speaker described further the construction of various auxiliary appliances, in particular the casings for the Pupin coils, their switch covers and switch terminals. Finally he gave impressive figures showing the large quantities of materials used.

Communication of Dr. Keinath: Profile Instruments with a Straight Line Scale.

The speaker described and illustrated by models and slides the construction of profile instruments with a straight line scale, as built by Messrs. Siemens & Halske. In this design the pointer of the instrument is not connected, as usual, rigidly with a rotating coil, but has a transmission mechanism inserted between it and the coil in such a manner that the end of the pointer moves in a straight line.

Meeting of March 31, 1914

Paper by General Secretary L. Schüler on a New Electromagnetic Chiseler and Riveter.

The speaker started by enumerating the disadvantages of the compressed air hammers now used, which consist mainly in the necessity of using an expensive air compressor installation and the low efficiency of the tools. Mechanical hammers driven by an electric motor through a flexible shaft have not proved convenient either. The hammer designed by the speaker is based on electromagnetic attraction; in hammers of this kind one has to solve the difficult problem of cutting the exciting current in and out some twenty times per second, and the former attempts have all failed on account of the sparking produced. The process applied by the speaker consists in the utilization of the "switching-in shock" occurring with alternating currents. He uses for his hammer alternating current, and switches-in the current circuit at the zero point of the voltage curve, and then cuts it out again after the lapse of a complete period. The break is then sparkless, and all losses of magnetic energy are avoided. Hammers of different sizes were shown in operation, after which the speaker proceeded to a determination of the output and efficiency of such hammers, and showed by means of curves that, *e.g.*, a chipping hammer with an output of about 120 watts possesses an efficiency of about 60 per cent.

Paper by Dr. Linke on the Influence of the Shape of the Curves on the Operation of a Synchronous Converter.

The speaker discussed the difficulties which arise in the operation of synchronous converters when the shape of

the curve of the working current differs materially from the shape of the curve proper to the converter itself. There occurs then the appearance of an alternating current of high frequency superimposed over the direct current delivered by the converter, and this alternating current attains particularly high values when the converter works in parallel with a storage battery. The speaker showed numerous oscillographic curves which gave an idea of the kind and magnitude of the superimposed currents, and recommended, as a means for obviating this undesirable phenomenon, to insert a reactor between the converter and transformer.

Meeting of April 28, 1914

Paper by Dr. L. Lichtenstein, on The Testing of Power Current Cables and their Laying, with Particular Regard to High-Tension Direct Currents.

The speaker sketched the difficulties which one meets in testing long stretches of cable carrying high-tension currents. The cable takes a very high charging current, and therefore, either the testing transformer has to be built for a very large output, or large reactance coils have to be placed in parallel with the cable to compensate for the charging current. Either of the two is particularly troublesome when cables already laid are to be tested, and the testing installation has therefore to be moved from place to place. These difficulties could be eliminated by using direct current for testing purposes. The Delon high-tension rectifier can be used for this purpose. The speaker showed the construction and way of operation of this apparatus, particularly the movable type built by the Siemens-Schuckert Works. The latter consists of a gasoline engine with an alternating-current generator directly connected, and a high-tension rectifier coupled on, as well as a high tension transformer for an output of 6 kv-a. The speaker gave further a series of test data referring to the determination of the available d-c. voltage from the primary voltage of the transformer, as well as comparative data on the d-c. and a-c. voltages necessary to break down given thicknesses of insulation.

Paper by A. Steinhardt on the Large Electric Kitchen Installation in the New Administration Building of the Siemens-Schuckert Works in Siemensstadt near Berlin.

In the dining hall of the new administration building of the Siemens-Schuckert Works there dine daily from two to three thousand persons. The meals are prepared in a large kitchen which is operated electrically throughout. The speaker described in detail the arrangement of the various cooking utensils, ovens, etc., as well as the numerous auxiliary apparatus, also electrically driven. This kitchen installation is the largest in existence with purely electric drive throughout. According to the showing made by the speaker, with current at 5 pfennigs (say 1.25 cents) per kw-hr., the cost of operation is not higher than in kitchens of the same size operated on coal, gas, or steam heat.

Societe Internationale Des Electriciens

Meeting of March 4, 1914

"The Probable Progress in Receiving Wireless Telegraphic Waves from Long Distances," by Henri Abraham.

M. Henri Abraham experimented this winter at Washington, D. C. with the direct galvanometric registration of the wireless telegraph waves sent out by the experimenters on the Eiffel Tower in Paris, a distance of 6200 km. The author presents the photographic records obtained by the photographic reproduction of the currents using a galena detector. On certain photographs the displacement of the point of light reached one centimeter for a single spark produced at the Eiffel tower. This displacement corresponds to a power of about three thousandths of a microcoulomb (the sensitiveness of the galvanometer was 250 millimeters per microampere, returning to zero in

a tenth of a second). During the experiments, and depending on the meteorological conditions, the intensity of the current varied in the ratio of 100 to 1, with a maximum during a very cold spell.

The author indicates how one may consider the transmission of wireless telegraph waves over the world. The Hertzian rays would pass in a curved line, very high above the surface of the sea; they might even pass beyond the limits of the atmosphere altogether.

M. Abraham also calls to mind another property, which is not very well known in wireless detectors (crystal valve, balometer, etc.). Experiments show that for weak waves the rectified currents are not proportional to the amplitudes of the waves: *The direct current furnished by the detector diminishes as the square of the respective alternating current.*

The capacity of the detector becomes therefore more and more feeble in a measure as the intensity of the waves diminishes, in long-distance wireless telegraphy, and this progressive reduction of production exaggerates the variations observed in the receiving of the waves.

Independent of the attempts to perfect the apparatus for the emission of waves, it is certainly possible to find means for the receiving of currents which will give good reproduction of weak waves and which will permit us to increase the facility of receiving and sending messages by wireless telegraphy.

Meeting of April 1, 1914

Work Done in the Central Electrical Laboratory—Summary of Photometric Tests of Kinematographic Apparatus, by F. Laporte.

This simple notice does not pretend to be a systematic study of the kinematograph; its only purpose is to show that even very summary tests give very different results with apparatus of different types. After having measured the distance of projection and the size of the image on the screen, all that was done was to measure the consumption of electric energy by the luminous source, and to determine photometrically the lighting of the screen, the dispositive being either in motion or at rest, but, of course, without an interposing film.

The useful luminous flux was found to be equal to the product of the lighting of the screen by the area of the image and the luminous utilization of the energy consumed may be characterized by energy-flux expressed in lumens per watt. The table of results obtained shows that with the apparatus used in the tests (arc lighting) from 13 to 277 millilumens per watt were obtained on the screen.

It appears, therefore, that by means of measurements of the lighting of the image, much facilitated now by the use of portable photometers or luxmeters, it wou d be possib'e to improve the apparatus or at least to facil tate considerab y the regulation of the optical system.

Mercury Vapor Lamp with Two Electrodes for Alternating Current, by Maurice Leblanc Jr. and Darmois.

The present mercury vapor lamps (glass or quartz) are for direct current; on an alternating current they do not light, and one observes only a short spark when the starting short circuit is broken. This is probably a result of the properties of the cathode of the arc, which, in order that the arc should persist, must all the time emit negative electrons. When each electrode in turn becomes anode or cathode, the arc will continue only if the electrode which becomes a cathode be enabled to emit such electrons. These considerations explain the action of the mercury valve, and the authors have exhibited such a valve delivering a current of 3.5 amperes at 1000 volts d-c. between the anodes of the bulb there is a potential of 2200 volts a-c. without a direct arc being produced between them.

The same considerations show the importance, for the starting of an alternat-

ing-current arc, of the thermal conductivity of the electrodes and of the inductance of the circuit. It is actually possible to start and maintain an alternating-current arc between two mercury electrodes. The lamp is the same as that described for use with direct current in a previous paper (Société Francaise de Physique, June 11, 1912, Lamp without Internal Vacuum Space); it is connected in series with a convenient self-inductance in an alternating circuit with an e.m.f. above 600 volts. The starting of the arc is produced by breaking the mercury column just as in a d-c. lamp. The authors showed in slides the curves of voltages at the arc terminals, self-inductance terminals, etc. They show that at each alternation of the current the arc goes out for an appreciable length of time (approximately 1/1000 sec.), and its relighting is shown by a very well marked peak in the voltage curve. The following are the conditions which permit flattening this peak, which is very inconvenient for the proper functioning of the lamp: increase of current, reduction of the free surface of the electrodes, increase of the length of the arc and increase of the vapor pressure. At a higher pressure the peaks disappear; the power factor of the lamp becomes normal (0.75 to 0.80), and the luminous efficiency excellent (5 candles per watt), and it becomes even possible to make the arc work with a resistance in series.

Meeting of May 6, 1914

On the Oscillating Spark as an Economic Source of Ultra-Violet Rays, and Some Applications, by J. de Kowalski.

Up to the present time mercury vapor lamps with electrodes have been exclusively used in practise as a source of rays corresponding to the ultra-violet, for sterilization purposes and photochemical reactions. It is true that scientific experiments have been tried in which it was attempted to make rays of different origin act on substances enclosed in quartz vessels; as sources of the rays, iron arcs, carbon arcs, sparks between electrodes of magnesium, zinc, aluminum, iron, cadmium, etc., have been used, but these experiments have not been successful, and the efficiency obtained with devices of this kind was on the average quite poor. The author thought that by varying the electric conditions of the oscillating circuit, one could exert an influence of a certain kind on the radiating energy in the different regions of ultra-violet radiation. With this purpose in view, he undertook a series of investigations, which led to the following conclusions: (1) as one increases the amplitude of the current in the oscillating circuit, one finds that the region which corresponds to the maximum of radiating energy is displaced towards the shorter length of waves; (2) the length of wave which is found to correspond to the maximum of radiating energy, is the shorter, the better the spark is damped out (one could express it by saying that the length of the wave corresponding to the maximum of radiating energy is displaced towards the extreme ultraviolet in proportion as the energy consumed in the spark is increased); (3) a series of tests with different electrodes has established that the place of the length of wave corresponding to a maximum of radiating energy depends also, in the ultra-violet spectrum, on the nature of the electrodes, and, in particular, this position is not the same for alloys and pure metals.

Tests on sterilization of large amounts of water performed in collaboration with Professor Glucskmann, director of the Institute of Hygiene at Freiburg show that, when the above conditions are practically applied, not only does the theoretical radiating energy increase but the ultra violet energy in the oscillating spark can be increased to such an extent that the rays emitted can be used with good economic results either for sterilization, or for photochemical reactions. As a source of ultra-violet rays, the oscillating spark has the great advantage, as compared with the mercury vapor lamp, that it does not

necessitate, like the latter, a quartz envelop which absorbs a large part of the ultra-violet rays (according to Pfluger, 20 per cent), and, among them, absorbs just those which have the greatest abiotic power. By selecting for the electrodes metals which do not pulverize much during the spark discharge, the latter may be made to act directly on the water.

Library Accessions

The following accessions have been made to the Library of the Institute since the last acknowledgment.

To May 15

Alternating Current Commutator Motor, and the Leakage of Induction Motors. By Rudolph Goldschmidt. London, 1909. (Purchase.)

Bericht uber die Feierliche Enthüllung des Denkmales zu ehren des Erbauers der Osterreichischen Alphenbahnen K. K. Sektionschef und Eisenbahnbaudirektor Karl Wurmb, Oct. 13, 1913. n.p. n.d. (gift of Oesterreich Ingenieur und Architekten Vereines)

La Cémentation de L'Acier. Frederic Giolitti. Traduction francaise revue par Albert Portevin. Paris, A. Hermann et Fils, 1914. (Gift of publishers.) Price 16 fr.

A translation from the Italian of Frederic Giotti professor of metallurgy in the University of Turin. It is a most exhaustive treatment of the cementation process and its applications. W. P. C

Complete Treatise on the electro-deposition of metals translated from the latest German edition of Geo. Langbein, with additions by William T. Brannt, Philadelphia, 1913. (Purchase.)

Cyclopedia of Applied Electricity, vols. 1-7, Chicago, 1914. (Purchase.)

List of Electrical Fittings published by the National Board of Fire Underwriters, April, 1914. (Gift of National Fire Protection Association.)

National Fire Protection Convention, Philadelphia, Oct. 13-18, 1913, Official Record of the First American. Philadelphia, Merchant & Evans Co., 1914. (Gift of Publishers.)

Rapport sur l'unification des Abreviations Bibliographiques dans les mémoires de Chimie. By A. Guye, Geneve, 1914. (Gift of author.)

Royal Society of London. Philosophical Transactions Series B, vol. 204. London, 1914. (Gift of Adams Fund.)

Soren Hjorth. Inventor of the Dynamo-electric principle. By Sigurd Smith. Kobenhavn, 1912. (Gift of Elektroteknisk Forening.)

Switches and Switchgear. By R. Edler, translated by Ph. Laubach, New York, 1913. (Purchase.)

Traité de Physique. Par O. D. Chwolson. Tome cinquième, prémier fascicule. Paris, A. Hermann et Fils, 1914. (Gift of publisher.) Price 9 fr.

This French translation of Professor Chwolson's work on physics, has now reached the fifth volume in this revision. The whole part, 266 pages, is devoted to the magnetic field. W. P. C.

Water Hammer in Hydraulic Pipe Lines. By A. H. Gibson, London, 1908. (Purchase.)

Western Union Telegraph Company. Annual Report 1913. New York, 1914. (Gift of Company.)

Gift of American Electric Railway Association

Illinois Railroad and Warehouse Commission. Annual Report 42, 1912.

Indiana Railroad Commission. Annual Report 5th, 1910.

Kansas Public Utilities Commission. First Report, May 1911 Nov. 1912.

Kentucky Railroad Commission. Annual Report 33, 1912.

New York (State) Public Service Commission. Reports of Decisions from July 1, 1907-May 7, 1913, vols. 1-3.

Rhode Island Public Utilities Commission. Annual Report 1912.

South Dakota Railroad Commissioners. Annual Report 23, 1912.

Gift of J. W. Lieb, Jr.

Beck, Theodor. Beiträge zur Geschichte des Maschinenbaues. Ed. 2. Berlin, 1900.

Il Codice Atlantico di Leonardo da Vinci. 1 vol. in 6, (3 text, 3 plates.) Milano, 1894.

Herzfeld, Marie von. Leonardo da Vinci, Der Denker, Forscher und Poet. Jena, 1911.

——Leonardo da Vinci. Traktat von der Malerei. Jena, 1909.

Houssaye, Arsène. Histoire de Leonard de Vinci. Ed 2. Paris, 1869.

McCurdy, Edw., Leonardo da Vinci's note book. London, 1907.

Muntz, Eugène, Leonardo da Vinci, Artist, Thinker and Man of Science. 2 vols. Lond. N. Y., 1898.

Feldhaus, F. M., Leonardo der Techniker und Erfinder. Jena, 1913.

Trade Catalogues

Allegemeine Elektricitäts Gesellschaft. Berlin Germany. Abbildungen ausgefuhrter Uhren-Anlagen. 37 pp. Anlasser in Kontrollerform (Schaltwalzen-Anlasser) Drahtlampen für Automobil-Beleuchtung. 4 pp. Drehstrommotoren, Type V.D. aum antrieb von Zentrifugalpumpen.

Chicago Pneumatic Tool Co., Chicago, Ill. Bull. 152. "Chicago Gatling" drills. Feb. 1914.

Chicago Pneumatic Tool Co. Chicago, Ill. Bulletin E-31. Duntley Electric Sensitive Drilling Stand. Mch. 1914.
——E-32. Duntley Electric Tool for Street and Interurban Railways. Mch. 1914.
Delta-Star Electric Co., Chicago, Ill. Bull. 3. Outdoor high tension equipment "P-M" "P-M-B" switches, etc. Mch. 1914.
——Bull. 12. Moderate capacity outdoor high tension sub-stations. March 1914.
Electric Storage Battery Co. Philadelphia, Pa. Bull. 145. Improvements in End Cell Switches. Feb. 1914.
Electric Storage Battery Co., Philadelphia, Pa. "Exide" Vehicle batteries. Receiving a new battery and operating instructions.
Elektrisch angetriebene Zentrifugalpumpen für Grundwasserabsenkungen.
Elektrische Antriebe in Eisenbahnwerkstatten. Magnet and Nebenschluss—Regulatoren. 7pp.
Emerson Electric Mfg. Co. St. Louis, Mo. Bull. No. 3508. Direct connected exhaust fans. Mch. 5, 1914.
——no. 3913. Motors for family sewing machines. Mch. 12-1914.
General Electric Co., National Lamp Works, Cleveland, O. Bull. 8E. Mazda Miniature lamps. March 10, 1914.
——Bull 11B. Mazda street series lamps. April 10, 1914.
——Bull 13D. High candle power multiple lamps. April 1, 1914.
——Bull. no. 44590. Type ML Governor for motor-driven air compressors. Jan. 1914.
——no. 47400. Type F, form K12 oil switches.
——Street lighting fixtures for the new sizes of Mazda series lamps.
Koehring Machine Co. Milwaukee, Wis. The Mixer. Jan-March 1914.
Luminous Unit Co., St. Louis, Mo. Catalog 3 Brascolite illuminations.
New York Air Brake Co., New York, N. Y. Catalogue air brake apparatus. Sept. 1913
Santo. Bohner zum Reinigen und Einwachsen und zum Bohnern von Parkett und Linoleum. Die systematische pflege der Elektrizitätsnähler 42 pp.
Ozone Pure Airifier Co. Chicago, Ill.
Ozone. Description.
Ozoning the air.
Loss by your office staff.
What is Ozon ?
Philadelphia Electric Co. Philadelphia, Pa. Bulletin March 1914.
Sprague Electric Works. New York, N. Y. Bull. no. 242. Sprague Electric Control systems for newspaper and rotary Magazine pressers.
——Bull. No. 41010. Direct current motors types C. and D. Electric Fans, 1914. Labratory Ozone Apparatus, March 1914.
Standard Underground Cable Co., Pittsburgh, Pa Bull 200-I. Specifications for Standard C.C.C. wire. April 1914.
——400-I. Weatherproof Insulated Wires and Cables. March 1914.
Werkzeugmaschinen Antriebe—Einständer Stoss-Maschine mit regelbaren Umkehrmotor.
——Gross Tischhohelmaschinen mit regelbarem umkehrmotor.
——Plandrehbank mit regelbarem motor Zähler-Fabrik. 28 pp.

UNITED ENGINEERING SOCIETY

Conservation Law of the State of New York, as amended to the close of the regular session of 1913. Albany, 1913.
——in relation to Fish and Game and to the Lands and Forests, 1913. Albany, 1913. (Gift of Conservation Commission.)
Guide to the Current Periodicals and Serials of the United States and Canada. Ed. 3, 1914. By H. O. Severance. Ann Arbor, 1914. (Purchase.)
History of the E. I. du Pont de Nemours Powder Company. New York, 1912. (Gift of E. I. du Pont de Nemours Powder Co.)
Industrial Arts Index. 1913. White Plains, 1914. (Purchase.)
International Whitaker, 1914. London, 1914. (Purchase.)
Moody's Manual of Railroads and Corporation Securities. vol. I—Railroad Section. New York, 1914. (Purchase.)
Nebraska State Railway Commission. Annual Report to the Governor 6th, 1913. Lincoln, 1914. (Gift of Nebraska State Railway Commission.)
New York Public Library. Annual Report, 1913. New York, 1914. (Gift of New York Public Library.)
Oil, Paint and Drug Reporter. Green Book for Buyers, Jan. 1914. New York, 1914. (Gift of Oil, Paint & Drug Reporter.)
Postalization of the Telephone and the Telegraph. Speech of Hon. David J. Lewis, in House of Representatives, Jan. 16, 1914. (Gift of D. J. Lewis.)
Trust Legislation. Hearings before the Committee on the Judiciary, House of Representatives, 63d Congress. Vols. 1-2. Washington, 1914. (Gift of U. S. House of Representatives Committee on the Judiciary.)
Wisconsin Industrial Commission. Proposed Building Code. Madison, n.d. (Gift of Industrial Commission).

TO JUNE 15

American Telephone & Telegraph Company. Brief of Arguments against Public Ownership. vols. 1-3. New York, n.d.
——Telephone Memoranda. A few facts and and opinions—foreign and domestic. New York, n.d.
——Extracts from the Report of the Royal Commission appointed to investigate the postal, telegraph and telephone services of the Commonwealth of Australia.

——Governmental and Private Telegraph and Telephone utilities: an analysis. New York, n.d. (Gift of American Telephone & Telegraph Company.)

American Wood Preservers Association. Proceedings of 10th Annual Meeting, 1914. Baltimore, 1914. (Gift of Association.)

Der Ausbau der Niederdruck-Wasserkräfte nach wirtschaftlichen Grundsätzen. By Adolph Ludin. Heidelberg, J. Hörning, 1910. (Gift of author.)

A study of the commercial utilization of water powers of low head, and their application to power transmission. The treatment is mathematical, and economical, the details in installations being discussed from the economical standpoint, should be of particular interest to engineers studying the development of water powers along canals. W.P.C.

Dispositivi per migliorare il fattore di potenza sulle reti a correnti trifasi Risultati practici raggiunti. By G. Sartori. n.p. 1914. (Gift of author.)

Electric Light Accounts and their significance. By H. M. Edwards. New York, 1914. (Purchase.)

Electric Motors, their action, control and application. Ed. 2. By F. B. Crocker and Morton Arendt. New York, D. Van Nostrand Co., 1914. Price $2.50. (Gift of Publishers.)

A revised edition of this well known work on the operation of electric motors. An entire chapter on Power Requirements for Different Purposes has been added. W.P.C.

Elektrotechnischen Zeitschrift. General register. 1890-1902. Berlin, 1904. (Purchase.)

First Aid in case of Electric Shock. New York, 1913. (Gift of New York Edison Company.)

Bau grosser Elektrizitätswerke. II Band. By G. Klingenberg. Berlin, 1914. (Purchase.)

Maryland. Public Service Commission. Report 1913. Baltimore, 1914. (Gift of Commission.)

McGraw Electric Railway Manual. 1914. New York, McGraw Publishing Co., 1914. (Gift of Electric Railway Journal.)

McGraw Electrical Directory. Lighting and Power Edition. April 1914. New York, 1914. (Purchase.)

On the Mining, Preparation and Uses of Mica. By H. P. Wiggins. n.p. n.d. (Gift of author.)

New York (State) Department of Labor. Annual Report of the Commissioner. 13th, 1913. Albany, 1914. (Gift of Department of Labor.)

Royal Society of London. Index to the Proceedings vols. 1-75, 1800-1905. London, 1913. (Gift of E. D. Adams.)

Safety Rules and Regulations of The New York Edison Company New York, 1913. (Gift of New York Edison Company.)

Societe Internationale des Electriciens. Annuaire. 1914. Paris, 1914. (Exchange.)

Statement of Bion J. Arnold, Chairman Board of Supervising Engineers Chicago Traction with reference to the report dated April 28, 1914, of Barrow, Wade, Guthrie & Co., Accountants made to Hon. J. E. Traeger, City Comptroller, City of Chicago upon the accounts of the Chicago City Railway Company. Chicago, 1914. (Gift of B. J. Arnold.)

Telephone Pioneers of America. Proceedings of 3d Annual Convention, 1913. New York, 1913. (Gift of Telephone Pioneers of America.)

Trade Catalogues

Allgemeine Elektricitäts Gesellschaft. Berlin, Germany. Lade und Loschvorrichtungen. 14 pp.

Messinstrumente. Megger und ducter, 8 pp.

Selbsttätige Anlassvorrichtungen für neiderspannungs Drehstrommotoren.

——für Hochspannungs "

Werkzeugmaschinen-Antriebe. Drehbank-Druckknopfsteurungen.

——Lederwalzen Antrieb mit Umkehr motor.

Babcock & Wilcox Co. New York, N. Y. Forged steel water tube marine boilers. Ed. 2. 1914.

Central Electric Co. Chicago, Ill. Electron May, 1914.

Connersville Blower Co. Connersville, Ind. Bulletin10A. Type H Blower. Dec. 1913.

——Bulletin 19. Connersville Valveless Magna Pump. Mch. 26, 1914.

Consolidated Expanded Metal Co's. Pittsburgh, Pa. Universal Slab Computer.

——Steelcrete Guards. 34 pp.

Fort Wayne Electric Works. Fort Wayne, Ind. Bulletin 46203. Type K5 Single-phase Watthour meters. March 1914.

General Electric Co. Schenectady, N. Y. Bull. 46291. Portable test meter-type IB-5 for Alternating current circuits March 1914.

Koehring Machine Co. Milwaukee, Wis. Koehring Mixer. May, 1914.

Ohio Brass Co. Mansfield, O. Catalogue No. 14. Overhead materials, Rail Bonds, Car Equipment Specialties and High Tension Porcelain Insulators. 1914.

Spécialité de Fondations en terrains compressibles aquiferes, de remblais ou maniers. (Système Breveté.) 125 pp.

Sprague Electric Works of General Electric Co. New York, N. Y. No. 905. Electric Hoists. 31 pp. 1914.

No. 331 Electric Fans 1914.

" 953 Theatrical Devices. Iris Shutter Color Disc. 1914.

" 950. Theatrical Devices. Plug Connectors. 1914.

" 951. Theatrical Devices. Stage floor and wall pockets. 1914.

" 952. Theatrical Devices. Strip Lights, Proscenium Lights, Border Lights, etc. 1914.

" 441. Watertight floor boxes. 1914.

Société Anonyme des Pieux Armes Frankignoul Liége, Belgium.

UNITED ENGINEERING SOCIETY

Bibliographie der Deutschen Zeitschriften-Literatur. Band XXXIII, 1913. By F. Dietrich. Leipzig, 1914. (Purchase.)

Deutsches Rettungswesen. Berlin, 1913. (Purchase.)

Dictionnaire Autotechnique en quatre Langues. vols. 2, 3, 4. By R. Schmidt. Leipzig, 1906-08. (Purchase.)

Engineers Club of Boston. By-laws, Officers and List of Members, 1914. Boston, 1914. (Gift of Engineers Club of Boston.)

New International Encyclopaedia. Ed. 2. vols. 1-2. New York, 1914. (Purchase.)

New York Times Index. Jan.-March, 1914. New York, 1914. (Purchase.)

Spanish-English Dictionary of Mining Terms. By F. Lucas. London, 1905. (Purchase.)

Die Technik der Vorzeit, der Geschichtlichen zeit und der Naturvolke. By F. M. Feldhaus. Leipzig, 1914. (Purchase.)

Technisches Wörterbuch für Werkzeugmaschinen und Maschinenwerkzeuge. By Chr. Elsner und Hugo Kriegeskotte. Berlin, 1910. (Purchase.)

Thermal Reactions in Carbureting Water Gas. By W. F. Rittman. New York, 1914. (Gift of author.)

Who's Who in New York, (City and State) 1914. New York, 1914. (Purchase.)

Das Zelluloid. By C. Piest, E. Stich and W. Vieweg. Halle, 1913. (Purchase.)

OFFICERS AND BOARD OF DIRECTORS, 1913-1914

PRESIDENT.

(Term expires July 31, 1914.)

C. O. MAILLOUX.

JUNIOR PAST-PRESIDENTS.

GANO DUNN.

RALPH D. MERSHON.

VICE-PRESIDENTS.

(Term expires July 31, 1914.)	(Term expires July 31, 1915.)
A. W. BERRESFORD.	J. A. LIGHTHIPE.
WILLIAM S. MURRAY.	H. H. BARNES, JR
SEVERN D. SPRONG.	CHARLES E. SCRIBNER.

MANAGERS.

(Term expires July 31, 1914.)	(Term expires July 31, 1915.)	(Term expires July 31, 1916.)
F. S. HUNTING.	COMFORT A. ADAMS.	H. A. LARDNER.
NORMAN W. STORER.	J. FRANKLIN STEVENS.	B. A. BEHREND.
WILLIAM S. LEE.	WILLIAM B. JACKSON.	PETER JUNKERSFELD.
FARLEY OSGOOD.	WILLIAM McCLELLAN.	LEWIS T. ROBINSON

TREASURER. (Term expires July 31, 1914.) **SECRETARY.**

GEORGE A. HAMILTON.

F. L. HUTCHINSON.

PAST-PRESIDENTS.—1884-1913.

*NORVIN GREEN, 1884-5-6.
*FRANKLIN L. POPE, 1886-7.
T. COMMERFORD MARTIN, 1887-8.
EDWARD WESTON, 1888-9.
ELIHU THOMSON, 1889-90.
*WILLIAM A. ANTHONY, 1890-91.
ALEXANDER GRAHAM BELL, 1891-2.
FRANK JULIAN SPRAGUE, 1892-3.
*EDWIN J. HOUSTON, 1893-4-5.
LOUIS DUNCAN, 1895-6-7.
FRANCIS BACON CROCKER, 1897-8.
A. E. KENNELLY, 1898-1900.
CARL HERING, 1900-1.
CHARLES P. STEINMETZ, 1901-2.
CHARLES F. SCOTT, 1902-3.
BION J. ARNOLD, 1903-4.
JOHN W. LIEB, Jr., 1904-5.
SCHUYLER SKAATS WHEELER, 1905-6.
SAMUEL SHELDON, 1906-7.
HENRY G. STOTT, 1907-8.
LOUIS A. FERGUSON, 1908-09.
LEWIS B. STILLWELL, 1909-10.
DUGALD C. JACKSON, 1910-11.
GANO DUNN, 1911-12.
RALPH D. MERSHON, 1912-13.

*Deceased.

HONORARY SECRETARY.

RALPH W. POPE,

33 West 39th Street, New York.

GENERA COUNSEL.

PARKER and AARON.

52 Broadway, New York

STANDING COMMITTEES

Revised to July 1, 1914.

EXECUTIVE COMMITTEE

C. O. MAILLOUX, Chairman,
90 West St., New York.
H. H. BARNES, JR., New York.
GANO DUNN, New York.
GEORGE A. HAMILTON, Elizabeth, N. J.
WILLIAM McCLELLAN, New York.
CHARLES E. SCRIBNER, New York.
J. FRANKLIN STEVENS, Philadelphia, Pa.

FINANCE COMMITTEE

J. FRANKLIN STEVENS, Chairman,
1326 Chestnut Street, Philadelphia, Pa.
A. W. BERRESFORD, Milwaukee, Wis.
S. D. SPRONG, Brooklyn, N. Y.

LIBRARY COMMITTEE

SAMUEL SHELDON, Chairman,
198½ Schermerhorn Street, Brooklyn, N. Y.
F. L. HUTCHINSON, New York.
F. B. JEWETT, New York.
MALCOLM MacLAREN, Princeton, N. J.
W. I. SLICHTER, New York.

MEETINGS AND PAPERS COMMITTEE

W. S. RUGG, Chairman,
165 Broadway, New York.
LEWIS T. ROBINSON, Secretary,
General Electric Company, Schenectady, N. Y.
L. W. CHUBB, Swissvale, Pa.
H. A. HORNOR, Philadelphia, Pa.
HENRY H. NORRIS, Ithaca, N. Y.
and the chairmen of the technical committees.

EDITING COMMITTEE

LEWIS T. ROBINSON, Chairman
General Electric Company, Schenectady, N. Y.
F. F. FOWLE, New York.
H. M. HOBART, Schenectady, N. Y.
M. G. LLOYD, Chicago, Ill.
A. S. McALLISTER, New York.
W. I. SLICHTER, New York.

CODE COMMITTEE

FARLEY OSGOOD, Chairman,
763 Broad Street, Newark, N. J.
B. A. BEHREND, Boston, Mass.
J. C. FORSYTH, New York.
H. B. GEAR, Chicago, Ill.
H. N. MULLER, Pittsburgh, Pa.
H. R. SARGENT, Schenectady, N. Y.
A. M. SCHOEN, Atlanta, Ga.
GEORGE F. SEVER, New York.
C. E. SKINNER, East Pittsburgh, Pa.

BOARD OF EXAMINERS

MAURICE COSTER, Chairman,
165 Broadway, New York.
W. G. CARLTON, New York.
A. S. McALLISTER, New York.
F. W. ROLLER, New York.
S. D. SPRONG, Brooklyn, N. Y.

SECTIONS COMMITTEE

P. M. LINCOLN, Chairman,
P. O. Box 911, Pittsburgh, Pa
C. L. CORY, Berkeley, Cal.
S. G. McMEEN, Columbus, Ohio.
W. S. RUGG, New York.
J. F. STEVENS, Philadelphia, Pa.
and the chairmen of all Sections, ex officio.

STANDARDS COMMITTEE

A. E. KENNELLY, Chairman,
Harvard University, Cambridge, Mass.
COMFORT A. ADAMS, Secretary,
Harvard University, Cambridge, Mass.
MORTON ARENDT, New York.
JAMES BURKE, Erie Pa.
W. A DEL MAR, New York.
W. C. L. EGLIN, Philadelphia, Pa.
H. W. FISHER, Perth Amboy, N. J.
H. M HOBART, Schenectady, N Y.
DUGALD C. JACKSON, Boston, Mass.
F. B. JEWETT, New York.
B. G. LAMME, Pittsburgh, Pa.
W. A. LAYMAN, St. Louis, Mo.
M. G. LLOYD, Chicago, Ill.
R. H. MARRIOTT, New York.
A. S. McALLISTER, New York.
WILLIAM McCLELLAN, New York.
W. L. MERRILL, Schenectady, N. Y.
W. S. MOODY, Pittsfield, Mass.
HAROLD PENDER, Boston, Mass.
W. H. POWELL, Milwaukee, Wis.
CHARLES ROBBINS, East Pittsburgh, Pa.
LEWIS T. ROBINSON, Schenectady, N. Y.
E. B. ROSA, Washington, D. C.
CHARLES F. SCOTT, New Haven, Conn.
CLAYTON H. SHARP, New York.
C. E. SKINNER, Pittsburgh, Pa.
JAMES M. SMITH, Ampere, N J.
CHARLES P. STEINMETZ, Schenectady, N.Y.
S. W. STRATTON, Washington, D. C.
PHILIP TORCHIO, New York.

LAW COMMITTEE

CHARLES A. TERRY, Chairman,
165 Broadway, New York.
CHARLES L. CLARKE, Schenectady, N. Y
CHARLES E. SCRIBNER, New York.
G. H. STOCKBRIDGE, New York.
W. B. VANSIZE, New York.

SPECIAL COMMITTEES

Revised to July 1, 1914

INDUSTRIAL POWER COMMITTEE

R. TSCHENTSCHER, Chairman,
Illinois Steel Company, South Chicago, Ill.
WILLIAM T. DEAN, Chicago, Ill.
A. C. EASTWOOD, Cleveland, Ohio.
E. FRIEDLAENDER, Braddock, Pa.
C. T. HENDERSON, Milwaukee, Wis.
CHARLES W. PARKHURST, Johnstown, Pa.
KARL A. PAULY, Schenectady, N. Y.
W. H. POWELL, Milwaukee, Wis.
B. R. SHOVER, Youngstown, Ohio.
ROBERT B. TREAT, East Orange, N. J.
BRENT WILEY, Pittsburgh, Pa.

TELEGRAPHY AND TELEPHONY COMMITTEE

F. F. FOWLE, Chairman,
68 Maiden Lane, New York.
M. H. CLAPP, St. Paul, Minn.
E. H. COLPITTS, New York.
M. M. DAVIS, New York.
S. P. GRACE, New York.
A. H. GRISWOLD, San Francisco, Cal.
JOHN L. HOGAN, Jr., Brooklyn, N. Y.
L. S. KEITH, Chicago, Ill.
S. G. McMEEN, Columbus, Ohio.
CLOYD MARSHALL, New York.
WILLIAM MAVER, Jr., New York.
J. H. MORECROFT, New York.
SAMUEL REBER, Washington, D. C.
F. L. RHODES, New York.
J. L. WAYNE, Indianapolis, Ind.
C. S. WINSTON, Chicago, Ill.
G. M. YORKE, New York.

ELECTROCHEMICAL COMMITTEE

A. F. GANZ, Chairman,
Stevens Institute of Technology, Hoboken, N. J.
C. F. BURGESS, Madison, Wis.
M. W. FRANKLIN, Bloomfield, N. J.
A. McK. GIFFORD, Pittsfield, Mass.
CARL HERING, Philadelphia, Pa.
BURTON McCOLLUM, Washington, D. C.
L. L. SUMMERS, Chicago, Ill.
W. R. WHITNEY, Schenectady, N. Y

COMMITTEE ON ELECTRICALLY PROPELLED VEHICLES

HAROLD PENDER, Chairman,
491 Boylston St., Boston, Mass.
A. CHURCHWARD, Boston, Mass.
G. H. JONES, River Forest, Ill.
ERNEST LUNN, Chicago, Ill.
FRANK W. SMITH, New York.
H. H. SMITH, Orange, N. J.
H. F. THOMSON, Boston, Mass.
P. D. WAGONER, Long Island City, N Y
F. E. WHITNEY, Philadelphia, Pa.
J L WOODBRIDGE, Philadelphia, Pa.

COMMITTEE ON USE OF ELECTRICITY IN MINES

WILFRED SYKES, Chairman,
Box 242, East Liberty, Pa.
C. W. BEERS, Wilkesbarre, Pa.
GRAHAM BRIGHT, Wilkinsburg, Pa.
H. H. CLARK, Pittsburgh, Pa.
MARTIN H. GERRY, Jr., Helena, Mont.
J. M. HOPWOOD, Wheeling, W. Va.
J. T. JENNINGS, Pottsville, Pa.
B. T. VIALL, Miami, Arizona.
GEORGE R. WOOD, Philadelphia, Pa.

COMMITTEE ON USE OF ELECTRICITY IN MARINE WORK

C. S. McDOWELL, Chairman,
U. S. Navy, Navy Yard, New York.
D. M. MAHOOD, Secretary,
U. S. Navy Yard, Brooklyn, N. Y.
J. J. CRAIN, Quincy, Mass.
MAXWELL W. DAY, Schenectady, N.Y.
W. L. R. EMMET, Schenectady, N.Y.
F. C. HANKER, Wilkinsburg, Pa.
H. L. HIBBARD, Milwaukee, Wis.
GUY HILL, Brooklyn, N. Y.
H. A. HORNOR, Philadelphia, Pa.
O. P. LOOMIS, Newport News, Va.
G. A. PIERCE, Jr., Philadelphia, Pa.
ELMER A. SPERRY, Brooklyn, N. Y.
F. W. WOOD, New York.

PRIME MOVERS COMMITTEE

H. G. STOTT, Chairman,
600 West 59th Street, New York.
F. G. GASCHE, Chicago, Ill.
W. S. GORSUCH, New York.
P. JUNKERSFELD, Chicago, Ill.
DANIEL W. MEAD, Madison, Wis.
R. J. S. PIGOTT, New York.
G. I. RHODES, Boston, Mass.

ELECTROPHYSICS COMMITTEE

J. B. WHITEHEAD, Chairman,
Johns Hopkins University, Baltimore, Md.
EDWARD BENNETT, Madison, Wis.
H. L. BLACKWELL, Cambridge, Mass.
W. S. FRANKLIN, South Bethlehem, Pa.
E. P. HYDE, Cleveland, Ohio.
E. L. NICHOLS, Ithaca, N. Y.
G. W. PIERCE, Cambridge, Mass.
M. I. PUPIN, New York.
E. B. ROSA, Washington, D. C.
HARRIS J. RYAN, Stanford University, Cal.
CHARLES P. STEINMETZ, Schenectady, N.Y.
WILLIAM R. WHITNEY, Schenectady, N. Y

ELECTRIC POWER COMMITTEE

DAVID B. RUSHMORE, Chairman,
P. AND M., DEPT., General Electric Company.
Schenectady, N. Y.

E. A. LOF, Secretary.
P. AND M. DEPT., General Electric Company.
Schenectady, N. Y.

and the members of the following sub-committees:

1. *Power Stations.*

DUGALD C. JACKSON, Chairman.
Massachusetts Institute of Technology, Boston, Mass.
F. G. BAUM, San Francisco, Cal.
F. O. BLACKWELL, New York.
N. A. CARLE, Newark, N. J.
HUGH HAZELTON, New York.
A. H. KRUESI, Schenectady, N. Y.
B. G. LAMME, Pittsburgh, Pa.
J. A. LIGHTHIPE, Los Angeles, Cal.
IRVING E. MOULTROP, Boston, Mass.
L. L. PERRY, Chicago, Ill.
R. A. PHILIP, Boston, Mass.
A. E. POPE, Shelburne Falls, Mass.
FRANK SARGENT, Boston, Mass.
J. F. VAUGHAN, Boston, Mass.

2. *Power Generation Committee.*

H. W. BUCK, Chairman,
49 Wall Street, New York
ALLAN V. GARRATT, Holliston, Mass.
F. G. GASCHE, Chicago, Ill.
DANIEL W. MEAD, Madison, Wis.
S. D. SPRONG, Brooklyn, N. Y.

3. *Protective Apparatus.*

CHARLES P. STEINMETZ, Chairman,
General Electric Company, Schenectady, N. Y.
E. E. F. CREIGHTON, Schenectady, N. Y.
R. P. JACKSON, Swissvale, Pa.
N. J. NEALL, Boston, Mass.
FARLEY OSGOOD, Newark, N. J.
F. W. PEEK, Jr., Schenectady, N. Y.
JOHN H. RODDY, Charlotte, N. C.
R. F. SCHUCHARDT, Chicago, Ill.
S. D. SPRONG, Brooklyn, N. Y.
PERCY H. THOMAS, New York.

4. *Transmission*

P. W. SOTHMAN, Chairman,
17 Battery Place, New York.
H. W. BUCK, New York.
C. I. BURKHOLDER, Charlotte, N. C.
MARKHAM CHEEVER, Salt Lake City, Utah
V. G. CONVERSE, Niagara Falls, N. Y.
P. M. DOWNING, San Francisco, Cal.
O. H. ENSIGN, Los Angeles, Cal.
G. FACCIOLI, Pittsfield, Mass.
F. M. FARMER, New York.
VICTOR H. GREISSER, Spokane, Wash.
P. T. HANSCOM, Boston, Mass.
JOHN HARISBERGER, Seattle Wash.

4. *Transmission*—Continued

A. L. HARRINGTON, Raleigh, N. C.
R. S. KELSCH, Montreal, P. Q.
J. A. LIGHTHIPE, Los Angeles, Cal.
P. M. LINCOLN, Pittsburgh, Pa.
J. B. MAHONEY, Shelburne Falls, Mass.
C. S. MACCALLA, Spokane, Wash.
R. J. McCLELLAND, New York.
W. E. MITCHELL, Birmingham, Ala.
F. B. H. PAINE, New York.
R. A. PHILIP, Boston, Mass.
C. S. RUFFNER, St. Louis, Mo.
W. N. RYERSON, Duluth, Minn.
JULIAN C. SMITH, Montreal, P. Q.
R. M. WILSON, Westmount, Que.
T. A. WORCESTER, Schenectady, N. Y.

5. *Distribution.*

P. JUNKERSFELD, Chairman,
120 West Adams Street, Chicago, Ill.
E. J. BLAIR, Oak Park, Ill.
W. G. CARLTON, New York.
H. B. GEAR, Chicago, Ill.
HAROLD GOODWIN, Philadelphia, Pa.
P. M. LINCOLN, Pittsburgh, Pa.
E. B MERRIAM, Schenectady, N. Y.
W. S. MURRAY, New Haven, Conn.
RALPH H. RICE, Chicago, Ill.
PHILIP TORCHIO, New York.

6. *Economics*

WILLIAM McCLELLAN, Chairman,
141 Broadway, New York.
E. J. CHENEY, Secretary,
4 Bedford Road, Schenectady, N. Y.
FARLEY G. CLARK, Toronto, Ont.
W. S. GORSUCH, New York.
P. JUNKERSFELD, Chicago, Ill.
W. N. RYERSON, Duluth, Minn.
W. S. TWINING, New York.

7. *Engineering Data.*

PERCY H. THOMAS, Chairman,
2 Rector Street, New York.
N. A. CARLE, Newark, N. J.
F. F. FOWLE, New York.
H. M. HOBART, Schenectady, N. Y.
L. E. IMLAY, Niagara Falls, N. Y.
O. A. KENYON, New York.
A S McALLISTER, New York.
C. S. McDOWELL, New York.
HAROLD PENDER, Boston, Mass.
E. B. ROSA, Washington, D. C.
W. S. RUGG, New York.
C. E. SKINNER Pittsburgh, Pa.
C. W. STONE, Schenectady, N. Y.

ELECTRIC ILLUMINATION COMMITTEE

CLAYTON H. SHARP, Chairman,
556 East 80th Street, New York.
LOUIS BELL, West Newton, Mass.
FRANK CONRAD, Swissvale, Pa.
J. W. COWLES, Boston, Mass.
E. P. HYDE, Cleveland, Ohio.
A. E. KENNELLY, Cambridge, Mass.
C. F. LACOMBE, New York.
IRVING LANGMUIR, Schenectady, N. Y.
V. R. LANSINGH, Cleveland, Ohio.
PRESTON S. MILLAR, New York.
E. B. ROSA, Washington, D. C.
W. D'A. RYAN, Schenectady, N. Y.
G. H. STICKNEY, Harrison, N. J.

RAILWAY COMMITTEE.

FRANK J. SPRAGUE, Chairman,
165 Broadway, New York.
E. B. KATTE, Vice Chairman,
Grand Central Terminal, New York.
A. H. ARMSTRONG, Schenectady, N. Y.
F. W. CARTER, Rugby, England.
FREDERICK DARLINGTON, New York.
W. A. DEL MAR, New York.
C. E. EVELETH, Schenectady, N. Y.
W. S. GORSUCH, New York.
HUGH HAZELTON, New York.
E. R. HILL, New York.
W. S. MURRAY, New Haven, Conn.
A. S. RICHEY, Worcester, Mass.
CLARENCE, RENSHAW, Pittsburgh, Pa.
MARTIN SCHREIBER, Newark, N. J.
N. W. STORER, East Pittsburgh, Pa.
B. F. WOOD, New York.

COMMITTEE ON RECORDS AND APPRAISALS OF PROPERTIES.

W. B. JACKSON, Chairman,
111 W. Monroe Street, Chicago, Ill.
HAROLD ALMERT, Chicago, Ill.
BION J. ARNOLD, Chicago, Ill.
PHILANDER BETTS, Newark, N. J.
FRED A. BRYAN, South Bend, Ind.
H. H. CROWELL, Grand Rapids, Mich.
HENRY FLOY, New York.
WILLIAM McCLELLAN, New York.
H. S. PUTNAM, New York.
PAUL SPENCER, Philadelphia, Pa.
W. S. TWINING, New York.
B. F. WOOD, New York.

EDUCATIONAL COMMITTEE.

H. H. NORRIS, Chairman,
103 College Ave., Ithaca, N. Y.
F. C. BATES, New York.
G. A. DAMON, Pasadena, Cal.
C. R. DOOLEY, East Pittsburgh, Pa.
W. A. HILLEBRAND, Corvallis, Oregon.
J. P. JACKSON, Harrisburg, Pa.
G. W. LAMKE, St. Louis, Mo.
C. L. MEES, Terre Haute, Ind.
J. H. MORECROFT, New York.
A. J. ROWLAND, Philadelphia, Pa.
ROBERT SIBLEY, San Francisco, Cal.
CHARLES P. STEINMETZ, Schenectady, N. Y.

PUBLIC POLICY COMMITTEE.

CALVERT TOWNLEY, Chairman,
165 Broadway, New York.
WILLIAM McCLELLAN, Vice Chairman,
141 Broadway, New York.
W. H. BLOOD, Jr., Boston, Mass.
H. W. BUCK, New York.
J. J. CARTY, New York.
C. C. CHESNEY, Pittsfield, Mass.
JOHN H. FINNEY, Washington, D. C.
P. JUNKERSFELD, Chicago, Ill.
H. A. LARDNER, San Francisco, Cal.
L. A. OSBORNE, East Pittsburgh, Pa.
E. W. RICE, Jr., Schenectady, N. Y.
LEWIS B. STILLWELL, New York.
H. G. STOTT, New York.

PATENT COMMITTEE.

RALPH D. MERSHON, Chairman,
80 Maiden Lane, New York.
BION J. ARNOLD, Chicago, Ill.
C. S. BRADLEY, New York.
F. F. FOWLE, New York.
PETER COOPER HEWITT, New York.
JOHN F. KELLY, Pittsfield, Mass.
H. WARD LEONARD, Bronxville, N. Y.
M. I. PUPIN, New York.
A. H. TIMMERMAN, St. Louis, Mo.
W. E. WINSHIP, Newark, N. J.
B. F. WOOD, New York.

TECHNICAL LECTURES COMMITTEE.

W. I. SLICHTER, Chairman,
Columbia University, New York.
WILLIAM A. DEL MAR, Secretary,
N. Y. C. & H. R. R. R. Co.,
Grand Central Terminal, New York.
L. T. ROBINSON, Schenectady, N. Y.
W. S. RUGG, New York.
J. B. WHITEHEAD, Baltimore, Md.

SPECIAL COMMITTEE ON ORGANIZATION OF TECHNICAL COMMITTEES.

W. S. RUGG, Chairman,
165 Broadway, New York.
B. A. BEHREND, Boston, Mass.
H. W. BUCK, New York.
BANCROFT GHERARDI, New York.
F. S. HUNTING, Fort Wayne, Ind.

ENGINEERING COOPERATION COMMITTEE.

WILLIAM McCLELLAN, Chairman,
141 Broadway, New York.
H. H. BARNES, Jr., New York.
A. W. BERRESFORD, Milwaukee, Wis.
C. E. SCRIBNER, New York.
S. D. SPRONG, Brooklyn, N. Y.

MEMBERSHIP COMMITTEE

A. M. SCHOEN, Chairman,
Equitable Building, Atlanta Ga.
E. W. ALLEN, Chicago, Ill.
E. A. BALDWIN, Schenectady, N. Y.
F. J. BULLIVANT, St. Louis, Mo.
O. B. COLDWELL, Portland, Ore.
MAURICE COSTER, New York.
BANCROFT GHERARDI, New York.
A. H. LAWTON, New York.
S. J. LISBERGER, San Francisco, Cal.
N. J. NEALL, Boston, Mass.
K. C RANDALL, East Pittsburgh, Pa.
H. CLYDE SNOOK, Philadelphia, Pa.

CONSTITUTIONAL REVISION COMMITTEE

BANCROFT GHERARDI, Chairman,
15 Dey Street, New York.
F L. HUTCHINSON, Secretary, New York.
DUGALD C. JACKSON, Boston, Mass.
P. M. LINCOLN, Pittsburgh, Pa.
A. S. McALLISTER, New York.
WILLIAM McCLELLAN, New York.
W. S. MURRAY, New Haven, Conn.
W. S. RUGG, New York.
N. W. STORER, East Pittsburgh, Pa.
H. G. STOTT, New York.
P. H. THOMAS, New York.
CALVERT TOWNLEY, New York.
W. D. WEAVER, Charlottesville, Va.

U. S. NATIONAL COMMITTEE OF THE INTERNATIONAL ELECTROTECHNICAL COMMISSION

FRANCIS B. CROCKER, President,
14 West 45th St., New York.
A. E. KENNELLY, Secretary,
Harvard University, Cambridge, Mass.
C. A. ADAMS, Cambridge, Mass.
FREDERICK BEDELL, Ithaca, N. Y.
LOUIS BELL, West Newton, Mass.
J. J. CARTY, New York.
GANO DUNN, New York.
CARL HERING, Philadelphia, Pa.
H. M. HOBART, Schenectady, N. Y.
P. JUNKERSFELD, Chicago, Ill.
C. O. MAILLOUX, (*Ex Officio*) New York.
B. G. LAMME, Pittsburgh, Pa.
J. W. LIEB, Jr., New York.
E. B. ROSA, Washington, D. C.
CHARLES F. SCOTT, New Haven, Conn.
CLAYTON H. SHARP, New York.
SAMUEL SHELDON, Brooklyn, N. Y.
CHARLES P. STEINMETZ, Schenectady, N.Y.
HENRY G. STOTT, New York.
S. W. STRATTON, Washington, D. C.
ELIHU THOMSON, Lynn, Mass.

INDEXING TRANSACTIONS COMMITTEE.

GEORGE I. RHODES, Chairman,
111 Devonshire Street, Boston, Mass.

COMMITTEE ON CODE OF PRINCIPLES OF PROFESSIONAL CONDUCT.

GEORGE F. SEVER, Chairman,
13 Park Row, New York.
H. W. BUCK, New York.
GANO DUNN, New York.
JOHN F. KELLY, Pittsfield, Mass.
SCHUYLER SKAATS WHEELER,
Ampere, N. J.

INTERNATIONAL ELECTRICAL CONGRESS, SAN FRANCISCO, 1915.

EXECUTIVE COMMITTEE OF COMMITTEE ON ORGANIZATION.

CHARLES P. STEINMETZ, Honorary President of Congress.

E. B. ROSA, Honorary Secretary of Congress.

H. G. STOTT, Chairman,
600 West 59th Street, New York.

JOHN W. LIEB, Jr., Vice-Chairman,

C. O. MAILLOUX, Chairman, Sub-Committee on International Relations,

A. E. KENNELLY, Chairman, Sub-Committee on Program,

HENRY A. LARDNER, Chairman, Sub-Committee on Pacific Coast Relations,

H. H. BARNES, Jr., Chairman, Sub-Committee on Transportation.

GEORGE F. SEVER, Chairman, Sub-Committee on Entertainment.

PRESTON S. MILLAR, Secretary-Treasurer and Chairman, Sub-Committee on Publicity. 556 East 80th Street, New York.

F. L. HUTCHINSON, Secretary, A. I. E. E. (*Ex Officio*).

NEW YORK RECEPTION COMMITTEE.

A. H. LAWTON, Chairman,
55 Duane Street, New York.
H. H. BARNES, Jr., New York.
F. C. BATES, New York.
H. M. BRINCKERHOFF, New York.
W. G. CARLTON, New York.
MAURICE COSTER, New York.
D. C. DURLAND, New York.
H. W. FLASHMAN, New York.
HENRY, FLOY, New York.
J. W. LIEB, Jr., New York.
H. B. LOGAN, New York.
WILLIAM McCLELLAN, New York.
W. E. McCOY, New York.
F. A. MUSCHENHEIM, New York.
FARLEY OSGOOD, Newark, N. J.
F. A. PATTISON, New York.
C. E. SCRIBNER, New York.
GEORGE F. SEVER, New York.
SAMUEL SHELDON, Brooklyn, N. Y.
S. D. SPRONG, Brooklyn, N. Y.
PERCY H. THOMAS, New York.
CALVERT TOWNLEY, New York.
W. F. WELLS, Brooklyn, N. Y.

HISTORICAL MUSEUM COMMITTEE.

T. C. MARTIN, Chairman,
29 West 39th Street, New York.
JOHN J. CARTY, New York.
CHARLES L. CLARKE, Schenectady, N. Y.
LOUIS DUNCAN, New York.
E. W. RICE, Jr., Schenectady, N. Y.
CHARLES F. SCOTT, New Haven, Conn.
FRANK J. SPRAGUE, New York.

COMMITTEE ON RELATIONS OF CONSULTING ENGINEERS.

LEWIS B. STILLWELL, Chairman,
100 Broadway, New York.
FRANCIS BLOSSOM, New York.
H. W. BUCK, New York.
GANO DUNN, New York.
O. S. LYFORD, Jr., New York.
D. P ROBINSON, Chestnut Hills, Mass.

EDISON MEDAL COMMITTEE.

Appointed by the President for terms of five years.

Term expires July 31, 1918.
H. W. BUCK, New York.
J. FRANKLIN STEVENS, Philadelphia, Pa.
F. A. SCHEFFLER, New York.

Term expires July 31, 1917.
A. E. KENNELLY, Cambridge, Mass.
H. WARD LEONARD, Bronxville, N. Y.
ROBERT T. LOZIER, New York.

Term expires July 31, 1916.
FRANK J. SPRAGUE, New York.
SCHUYLER SKAATS WHEELER, Chairman,
Ampere, N. J.
W. D. WEAVER, Charlottesville, Va.

Term expires July 31, 1915.
ELIHU THOMSON, Lynn, Mass.
J. W. LIEB, Jr., New York.
E. L. NICHOLS, Ithaca, N. Y.

Term expires July 31, 1914.
PHILIP P. BARTON, Niagara Falls, N. Y.
J. J. CARTY, New York.
J. G. WHITE, New York.

Elected by the Board of Directors from its own membership for terms of two years.

Term expires July 31, 1915.
H. H. BARNES, Jr. New York.
WILLIAM McCLELLAN, New York.
S. D. SPRONG, New York.

Term expires July 31, 1914.
FARLEY OSGOOD, Newark, N. J.
RALPH D. MERSHON, New York.
CHARLES E. SCRIBNER, New York.

Ex-Officio Members.

C. O. MAILLOUX, President, New York.
GEORGE A. HAMILTON, Treasurer,
Elizabeth, N. J.
F. L. HUTCHINSON, Secretary,
New York.

INSTITUTE REPRESENTATIVES

ON BOARD OF AWARD, JOHN FRITZ MEDAL.

DUGALD C. JACKSON, Boston, Mass.
GANO DUNN, New York.
RALPH D. MERSHON, New York.
C. O. MAILLOUX, New York.

ON BOARD OF TRUSTEES, UNITED ENGINEERING SOCIETY.

GANO DUNN, New York.
CHARLES E. SCRIBNER, New York.
H. H. BARNES, Jr., New York.

ON LIBRARY BOARD OF UNITED ENGINEERING SOCIETY.

SAMUEL SHELDON, Brooklyn N. Y.
F. B. JEWETT, New York.
MALCOLM MacLAREN, Princeton, N. J.
W. I. SLICHTER, New York.
F. L. HUTCHINSON, New York

INSTITUTE REPRESENTATIVES

(Continued.)

ON ELECTRICAL COMMITTEE OF NATIONAL FIRE PROTECTION ASSOCIATION.

The Chairman of the Institute's Code Committee, Farley Osgood, Newark, N. J.

ON ADVISORY BOARD OF AMERICAN YEAR-BOOK.

EDWARD CALDWELL, New York.

ON ADVISORY BOARD, NATIONAL CONSERVATION CONGRESS.

CALVERT TOWNLEY, New York.

ON COUNCIL OF AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

W. S. FRANKLIN, South Bethlehem, Pa.
G. W. PIERCE, Cambridge, Mass.

ON CONFERENCE COMMITTEE OF NATIONAL ENGINEERING SOCIETIES.

CALVERT TOWNLEY, New York.
WILLIAM McCLELLAN, New York.

ON JOINT COMMITTEE ON ENGINEERING EDUCATION.

CHARLES F. SCOTT, New Haven, Conn.
SAMUEL SHELDON, Brooklyn, N. Y.

ON AMERICAN ELECTRIC RAILWAY ASSOCIATION'S COMMITTEE ON JOINT USE OF POLES

FARLEY OSGOOD, Newark, N. J.
F. B. H. PAINE, New York.
PERCY H. THOMAS, New York.

ON NATIONAL JOINT COMMITTEE ON OVERHEAD LINE CONSTRUCTION.

FARLEY OSGOOD, Newark, N. J.
F. B. H. PAINE, New York.
PERCY H. THOMAS.

ON NATIONAL COMMITTEE ON ELECTROLYSIS

BION J. ARNOLD, Chicago, Ill.
F. N. WATERMAN, New York.
PAUL WINSOR, Boston, Mass.

ON JOINT COMMITTEE ON LEGISLATION RELATIVE TO REGISTERING ENGINEERS.

WILLIAM McCLELLAN, New York.
S. D. SPRONG, New York.

ON BOARD OF MANAGERS, PANAMA-PACIFIC INTERNATIONAL ENGINEERING CONGRESS, 1915.

A. M. HUNT, San Francisco, Cal.
J. G. DeREMER, San Francisco, Cal.
And the PRESIDENT and SECRETARY of the Institute.

ON NATIONAL COMMITTEE OF INTERNATIONAL ILLUMINATION COMMISSION.

A. E. KENNELLY, Cambridge, Mass.
C. O. MAILLOUX, New York.
CLAYTON H. SHARP, New York.

LOCAL HONORARY SECRETARIES.

JAMES S. FITZMAURICE, G. P. O. Perth, Australia.
WILLIAM G. T. GOODMAN, Adelaide, South Australia.
GUIDO SEMENZA, N. 10, Via S. Radegonda, Milan, Italy.
ROBERT JULIAN SCOTT, Christ Church, New Zealand.
L. A. HERDT, McGill University, Montreal, Que.
HENRY GRAFTIO, St. Petersburg, Russia.
CLARE F. BEAMES, Bangalore, Mysore Province, India
RICHARD O. HEINRICH, Genest-str. 5 Schoeneberg, Berlin, Germany.
A. S. GARFIELD, 67 Avenue de Malakoff, Paris, France.

LIST OF SECTIONS

Revised to July 1, 1914.

Name and when Organized	Chairman	Secretary
Atlanta..........Jan. 19, '04	A. M. Schoen.	H. M. Keys, Southern Bell Tel. & Tel. Co., Atlanta Ga
Baltimore........Dec. 16, '04	J. B. Whitehead.	L. M. Potts, Industrial Building, Baltimore, Md.
Boston..........Feb. 13, '03	Harold Pender	Harry F. Thomson, Massachusetts Institute of Technology Boston, Mass.
Chicago.................. 1893	D. W. Roper.	E. W. Allen, 1028 Monadnock Building, Chicago, Ill.
Cleveland........Sept 27, '07	A. C. Eastwood.	R E. Scovel, 1663 East 86th Street, Cleveland, Ohio.
Detroit-Ann Arbor.Jan. 13, '11	A. R. Sawyer.	Ray K. Holland, Cornwell Building, Ann Arbor, Mich.
Fort Wayne......Aug. 14, '08	P. H. Haselton.	J. J. A. Snook, Fort Wayne Electric Works Ft. Wayne, Ind.
Indianapolis-Lafayette Jan. 12, '12	O. S. More.	G. B. Schley, 908 Hume-Mansur Building, Indianapolis, Ind.
Ithaca...........Oct. 15, '02	E. L. Nichols.	George S. Macomber, Cornell University, Ithaca, N. Y.
Los Angeles......May 19, '08	C. G. Pyle.	Edward Woodbury, Pacific Lt. & Pr. Corporation, Los Angeles, Cal.
Lynn............Aug. 22, '11	W. H. Pratt.	F. A. Hall, General Electric Co., Lynn, Mass.
Madison........Jan. 8, '09	J. W. Shuster.	F. A. Kartak, Univ. of Wisconsin, Madison, Wis.
Mexico..........Dec. 13, '07	Norman Rowe.	James Carson, Mexican Light and Power Company, Mexico City, Mexico.
Milwaukee.......Feb. 11, '10	L. L. Tatum.	W. J. Richards, National Brake and Electric Co. Milwaukee, Wis.
Minnesota.......Apr. 7, '02	Leo H. Cooper.	Emil Anderson, 1236 Plymouth Bldg., Minneapolis, Minn.
Panama.........Oct. 10, '13	Edward Schildhauer.	W. R. McCann, Isthmian Canal Commission, Culebra, Canal Zone.
Philadelphia......Feb. 18, '03	H. F. Sanville	W. F. James, 1115 North American Bldg., Philadelphia, Pa.
Pittsburgh.......Oct. 13, '02	J. W. Welsh.	Charles R. Riker, Electric Journal, Pittsburgh, Pa.
Pittsfield........Mar. 25, '04	G. W. Wade.	M. E. Tressler, General Electric Company, Pittsfield, Mass.
Portland, Ore.....May 18, '09	G. P. Nock.	R. F. Monges, G. E. Co., Electric Building, Portland, Ore.
St. Louis.........Jan. 14, '03	F. J. Bullivant.	A. McR. Harrelson, Emerson Electric Mfg. Co., St. Louis, Mo.
San Francisco...Dec. 23, '04	A. H. Griswold.	A. G. Jones, 819 Rialto Building, San Francisco, Cal.
Schenectady.....Jan. 26, '03	George H. Hill.	John R. Hewett, Gen. Elec. Co., Schenectady, N. Y.
Seattle..........Jan. 19, '04	S. C. Lindsay.	E. A. Loew, University of Washington, Seattle, Wash.
Spokane.........Feb. 14, '13	J. B. Fisken.	H. B. Peirce, Box 1436, Spokane, Wash.
Toledo..........June 3, '07	George E. Kirk.	Max Neuber, Cohen, Freidlander & Martin, Toledo, O.
Toronto..........Sept. 30, '03	D. H. McDougall.	H. T. Case, Continental Life Bldg., Toronto, Ont.
Urbana..........Nov. 25, '02	I. W. Fisk.	P. S. Biegler, University of Illinois, Urbana, Ill.
Vancouver.......Aug. 22, '11	E. M. Breed.	L. G. Robinson, 1003 Holden Building, Vancouver, B. C.
Washington, D.C..Apr. 9, '03	C. B. Mirick.	C. A. Peterson, Treasury Department, Washington, D. C.

Total.

LIST OF BRANCHES

Revised to July 1, 1914.

Name and when Organized.	Chairman	Secretary
Agricultural and Mechanical College of Texas.....Nov. 12, '09	D. B. Pickens.	E. C. Rack, A. & M. College, College Station, Tex.
Arkansas, Univ. of......Mar. 25, '04	S. S. McGill.	M. B. Roys, Univ. of Arkansas, Fayetteville, Ark.
Armour Institute........Feb. 26, '04	E. L. Nelson.	T. C. Bolton, Armour Inst. Tech., Chicago, Ill.
Bucknell University.....May 17,'10	F. O Schnure.	J. M. Hillman, Bucknell University, Lewisburg, Pa.
California, Univ. of......Feb. 9, '12	L. R. Chilcote.	E. S. Middaugh, University of California, Berkeley, Cal.
Cincinnati, Univ. of.....Apr. 10, '08	M. L. Harned	A. C. Perry, University of Cincinnati, Cincinnati, O.
Clemson Agricultural College..................Nov. 8, '12	F. J. Jervey.	F. H. McDonald, Clemson College, S. C.
Colorado State Agricultural College..........Feb. 11, '10	L. M. Klinefelter.	R. K. Havighorst. Colorado State Agricultural College, Fort Collins, Colo.
Colorado, Univ. of.......Dec. 16, 04	Philip S. Borden.	Charles S. Miller University of Colorado, Boulder, Colo.
Highland Park College..Oct. 11, '12	E. B. Williams.	Ralph R. Chatterton, Highland Park College, Des Moines, Iowa.
Iowa State College.....Apr. 15, '03	Earle G. Nichols.	F. A. Robbins, Iowa State College, Ames, Iowa.
Iowa, Univ. of.........May. 18, '09	J. H. Scanlon.	A. H. Ford, University of Iowa, Iowa City, Ia.
Kansas State Agr. Col...Jan. 10, '08	L. O'Brien.	W. C. Lane Kansas State Agric. Col., Manhattan, Kan.
Kansas, Univ. of.......Mar. 18, '08	H. C. Hansen.	L. M. Bocker, Univ. of Kansas, Lawrence, Kansas.
Kentucky State Univ. of.Oct. 14, '10	H. B. Hedges.	H. Tyler Watts, 315 East Maxwell Street, Lexington, Ky.
Lafayette College...... Apr. 5, '12	R. McManigal.	W. J. English, Jr., Lafayette College, Easton, Pa.
Lehigh University......Oct. 15, '02	N. F. Matheson.	F. C. Brockman, Lehigh University, S. Bethlehem, Pa.
Lewis Institute ....Nov. 8, '07	A. H. Fensholt.	Fred A. Rogers, Lewis Institute, Chicago, Ill.
Maine, Univ. of........Dec. 26, '06	C. M. Kelley.	E. L. Getchell. University of Maine, Orono, Maine.
Michigan, Univ. of......Mar. 25, '04	H. A. Enos.	H. W. Stubbs, University of Michigan, Ann Arbor, Mich.
Missouri, Univ. of......Jan. 10, '03	E. W. Kellogg	K. Atkinson University of Missouri, Columbia, Mo
Montana State Col......May 21, '07	John M. Fiske.	J. A. Thaler, Montana State College, Bozeman, Mont.

LIST OF BRANCHES—Continued

Name and when Organized	Chairman	Secretary
Nebraska, Univ. of......Apr. 10, '08	Olin J. Ferguson.	V. L. Hollister, Station A, Lincoln, Nebraska
New Hampshire Col......Feb. 19, '09		
North Carolina Col. of Agr. and Mech. Arts.......Feb. 11, '10	Wm.H.Browne,Jr.	James Fontaine, West Raleigh, N. C.
Ohio Northern Univ......Feb. 9, '12	A. B. Curtis,	W. F. Schott, Ohio Northern University, Ada, Ohio.
Ohio State Univ.........Dec. 20, '02	Leslie J. Harter.	Robert C. Schott, Ohio State Univ., Columbus, Ohio.
Oklahoma Agricultural and Mech. Col............Oct. 13, '11	A. P. Little.	Quentin Graham, 118 Husband St., Stillwater, Okla.
Oklahoma, Univ. of......Oct. 11, '12	R. D. Evans.	L. J. Hibbard, Univ. of Oklahoma, Norman, Okla.
Oregon Agr. Col.........Mar. 24, '08	A. O. Manigold.	I. L. Olmstead, Oregon Agric. Col., Corvallis, Ore.
Oregon, Univ. of........Nov. 11, '10	C. R. Reid.	C. H. Van Duyn, Univ. of Oregon, Eugene, Oregon.
Penn State College......Dec. 20, '02	A. D. Shultz,	A. T. McNeile, State College, Pa.
Pittsburgh, University of .Feb. 26, '14	B. E. O'Hagan	George Hickman, University of Pittsburgh, Pittsburgh, Pa.
Purdue Univ............Jan. 26, '03	L. W. Spray.	R. E. Tafel, Purdue University, Lafayette, Ind.
Rensselaer Poly. Inst....Nov. 12, '09	W. J. Williams,	H. F. Wilson Rensselaer Poly. Institute, Troy, N. Y.
Rose Polytechnic Inst....Nov. 10, '11	Charles F. Harris.	Claude A. Lyon, 1331 Liberty Avenue, Terre Haute, Ind.
Rhode Island State Col..Mar. 14, '13	W. C. Miller.	P. M. Randall, Jr., Rhode Island State College, Kingston, R. I.
Stanford Univ...........Dec. 13, '07	G. L. Beaver.	H. J. Scholz, Stanford University, Cal.
Syracuse Univ...........Feb. 24, '05	W. P. Graham.	R. A. Porter, Syracuse University, Syracuse. N. Y.
Texas, Univ. of.........Feb. 14, '08	Joseph W. Ramsey,	J. A. Correll. University of Texas, Austin, Tex.
Throop College of Technology...............Oct. 14, '10	W. L. Newton,	A. W. Wells, Throop Poly. Institute, Pasadena, Cal.
Virginia, Univ. of........Feb. 9, '12	Walter S. Rodman	H. Anderson, Jr., 1022 West Main St., Charlottesville, Va.
Wash., State Col. of....Dec. 13, '07	M. K. Akers.	H. V. Carpenter, State Coll. of Wash., Pullman, Wash.
Washington Univ........Feb. 6, '04	R. D. Duncan, Jr.	C. C. Hardy, Washington University, St. Louis, Mo.
Washington, Univ. of...Dec. 13, '12	H. W. McRobbie.	B. B. Bessesen, Univ. of Washington, Seattle, Wash.
Worcester Poly. Inst....Mar. 25, '04	Frank Aiken	A. B. R. Prouty, Worcester Poly. Inst., Worcester, Mass.
Yale University.........Oct. 03, 10	F. M. Doolittle	W. L. Kenly, New Haven, Conn.

Total, 48.

SECTION II

PROCEEDINGS

of the

American Institute

of

Electrical Engineers

Papers, Discussions and Reports

CONTENTS OF SECTION II

PROCEEDINGS

OF THE

American Institute

OF

Electrical Engineers.

Published monthly by the A. I. E. E., at 33 W. 39th St., New York, under the supervision of

THE EDITING COMMITTEE

GEORGE R. METCALFE, Editor

Subscription. $10 00 per year for all countries to which the bulk rate of postage applies.

All other countries $12.00 per year.

Single copy $1.00.

Subscriptions must begin with January issue.

Changes of advertising copy should reach this office by the 15th of the month, for the issue of the following month

Vol. XXXIII August, 1914 No. 8

Pacific Coast Convention, Spokane, Wash., September 9-11, 1914

The Pacific Coast Convention of the A. I. E. E. (298th meeting) will be held in Spokane, Washington, September 9-11, 1914, jointly with the annual convention of the Northwest Electric Light and Power Association, as announced in previous issues of the PROCEEDINGS.

Arrangements have been made with the railways for reduced rates (fare and one-third) from all points in the Western States and British Columbia, while from other points the regular summer tourist rates will be in force.

The following five papers will be presented in the A. I. E. E. sessions:

A Distribution System for Power Purposes, by F. D. Nims.

The Effect of Delta and Star Connections upon Transformer Wave Forms, by Leslie F. Curtis.

Economy in the Operation of 55,000-Volt Insulators, by M. T. Crawford.

Application of Electric Motors to Gold Dredges, by G. B. Rosenblatt.

Electrical Application in the Lumber Industry, by E. F. Whitney.

All of these papers, with the exception of that by Mr. Whitney, are printed in Section II of this issue.

The following papers are also promised:

Operation of the Butte, Anaconda and Pacific 2400-Volt Direct-Current Railway, by J. B. Cox and C. A. Lemmon.

The Big Creek Development of the Pacific Light and Power Corporation, by Edward Woodbury.

A Report of the Work Done by the California Joint Committee on Inductive Interference, by A. H. Babcock.

The program, as tentatively arranged, will be as follows:

SEPTEMBER 9, 1914.

Morning. Joint opening meeting with the Northwest Electric Light and Power Association, with address of welcome, followed by separate A. I. E. E. technical session.

Afternoon. A. I. E. E. technical session.

Reception to the visiting ladies, with afternoon tea, at the Davenport Hotel.

Evening. Joint smoker with N. W. E. L. & P. A. members.

Theater party for visiting ladies.

SEPTEMBER 10, 1914.

Morning. A. I. E. E. technical session.

Afternoon. Joint technical session. to discuss two papers to be presented by members of the N. W. E. L. & P. A.: "Rates and Physical Valuation," by W. W. Cotton, and "The Out-door Type of Transformer Station," by J. C. Martin.

An automobile trip around the city for the visiting ladies, ending with afternoon tea at the Country Club.

Evening. Joint meeting of members of the two organizations, including the visiting ladies. Illustrated lecture on the electrical features of the Panama-Pacific Exposition, and an address on the International Electrical Congress,

San Francisco, 1915, to be followed by a musical entertainment and buffet luncheon.

SEPTEMBER 11, 1914.

Morning. A. I. E. E. technical session.

Afternoon. A. I. E. E. technical session.

Automobile trip for the ladies, to Hayden Lake, with afternoon tea at Bozanta Tavern.

Evening. Joint banquet for members of the two organizations.

Theater party for the visiting ladies.

On the following two days, joint excursions are planned for the members of the two organizations, to include the ladies, as follows: on September 12, excursion by automobile to Little Falls and Long Lake; on September 13, trip over part of the Inland Empire Railway system to the Palouse country.

A. I. E. E. Standardization Rules

At the meeting of the Board of Directors of the Institute held at the Detroit Convention on June 25, the report of the Standards Committee, submitting to the Board the Standardization Rules as recommended for adoption by that committee, was presented, but consideration was postponed to an adjourned meeting to be held in New York on Friday, July 10, and an invitation was extended to the members of the Standards Committee and representatives of other societies who had collaborated in the work of the committee to attend this meeting for the purpose of a thorough discussion of the matter.

The meeting was held on July 10, and was attended by members of the Board, the Standards Committee, and others interested—31 in all. After a comprehensive discussion the following resolution was unanimously recommended to the Board of Directors for adoption.

Resolved, that the rules reported by the Standards Committee be, and hereby are, adopted to take effect on December 1, 1914, subject to editorial revision by the committee for the purpose of correcting errors and clarifying the real intent of the rules.

Later the Board convened in executive session and adopted the resolution as recommended. The proposed rules are printed in this issue of the PROCEEDINGS.

Resolutions were also adopted by the Board of Directors expressing appreciation of the services rendered to the Institute by Dr. A. E. Kennelly, chairman, Professor C. A Adams, secretary, and the other members of the Standards Committee, and its various sub-committees, in performing the arduous duty of revising the rules.

The National Electric Light Association and the Association of the Edison Illuminating Companies were also thanked for their cooperation with the Standards Committee in connection with this work.

Directors' Meeting, New York, July 10, 1914

A meeting of the Board of Directors of the Institute, adjourned from the Detroit meeting of June 25, was held at Institute headquarters, New York, on Friday, July 10, 1914.

There were present: President C. O. Mailloux, New York; Past-President Ralph D. Mershon, New York; Vice-Presidents H. H. Barnes, Jr., New York, A. W. Berresford, Milwaukee, Wis., S. D. Sprong, Brooklyn, N. Y.; Managers C. A. Adams, Cambridge, Mass., F. S. Hunting, Fort Wayne, Ind., P. Junkersfeld, Chicago, Ill., H. A. Lardner, San Francisco, Cal., William McClellan, New York, Farley Osgood, Newark, N. J., L. T. Robinson, Schenectady, N. Y., J. Franklin Stevens, Philadelphia, Pa.; Treasurer George A. Hamilton, and Secretary F. L. Hutchinson.

The principal business transacted at this meeting was the consideration of the report of the Standards Committee relative to the proposed revised Stand-

ardization Rules, which is referred to elsewhere in this issue.

Upon the recommendation of the Board of Examiners, the Board of Directors transferred four members of the Institute to the grade of Fellow and ten to the grade of Member, elected one applicant as a Member, and twelve as Associates, and ordered the enrolment of one student, in accordance with the lists printed in this issue of the PROCEEDINGS.

The action of the Finance Committee in approving monthly bills amounting to $7,842.78 was ratified.

On motion, it was voted that the appropriation of the Standards Committee be increased to $1500.00.

Recommended for Transfer to the Grade of Member, July 8, 1914

The Board of Examiners, at its regular monthly meeting on July 8, 1914, recommended the following Associates for transfer to the grade of Member. Any objection to these transfers should be filed at once with the Secretary.

D. W. BLAKESLEE, Superintending Erector, Kerr Turbine Company, Wellsville, N. Y.

S. O. SWENSON, Electrical Engineer, Kansas City Terminal Company, Kansas City, Mo.

Transferred to the Grade of Fellow July 10, 1914

The following were transferred to the grade of Fellow of the Institute at the meeting of the Board of Directors on July 10, 1914.

DAMON, GEORGE A., Consulting Engineer, Los Angeles, Cal., Dean, Throop College of Technology, Pasadena, Cal.

KETTERING, CHARLES FRANKLIN, Vice-President & General Manager, Dayton Engineering Laboratories Co., Dayton, Ohio.

MULLER, HENRY N., Supt. of Distribution, Duquesne Light Co., Pittsburgh, Pa.

WOOD, HARRY P., Professor of Electrical Engineering, Georgia School of Technology, Atlanta, Ga.

Total 4.

Transferred to the Grade of Member July 10, 1914

The following Associates were transferred to the grade of Member of the Institute at the meeting of the Board of Directors on July 10, 1914.

ALEXANDER, MAGNUS W., General Electric Co., West Lynn, Mass.

ALLAN, WILLIAM G., Designing Electrical Engineer, Toronto Power Co., Ltd., Niagara Falls, Ont.

ALLNER, FREDERICK A., General Supt., Pennsylvania Water & Power Co., Baltimore, Md.

CARY, WALTER, Vice-President and General Manager, Westinghouse Lamp Co., New York, N. Y.

CLAYTOR, WILLIAM G., Supt. Light & Power Dept., Roanoke & Electric Railway Co., Roanoke City, Va.

CUNNINGHAM, EDWARD ROBERT, Electrical Engineer, Oregon Electric & United Railways, Portland, Ore.

DEL MAR, WILLIAM A., Technical Assistant, Elec. Dept., N. Y. C. & H. R. R. R. Co., New York, N. Y.

JONES, HAMILTON MCRARY, Supt., Lighting Division, Porto Rico Railway & Power Co., Consulting Electrical Engineer, Government P. R. Irrigation Service, San Juan, P. R.

PARKER, RALZEMOND DRAKE, Engineer, American Telephone & Telegraph Co., New York, N. Y.

SNOW, JOHN EDWIN, Professor of Electrical Engineering, Armour Institute of Technology, Chicago, Ill.

Total 10.

Member Elected July 10, 1914

FAY, JOHN L., Distribution Supt., Union Electric Light & Power Co.; res., 3923 McPherson Ave., St. Louis, Mo.

Associates Elected July 10, 1914

ADAMS, HAROLD J., Student, University of Idaho, Kappa Sigma House, Moscow, Idaho.

AVERY, THAD, JR., Consulting Engineer and Contractor, Srinagar, Kashmir, India.

BLYMYER, LAFAYETTE WEBB, Electrician in Charge, Lincoln & Clune Electrical Advertising Co., 1020 Mills Bldg., San Francisco, Cal.

BRUG, FREDERICK A., Sales Engineer, National Carbon Co.; res., 83 Oppman Terrace, Cleveland, Ohio.

BURROUGHS, FAY F., Electrical Engineer, Mutual Fire Prevention Bureau, Oxford, Mich.

CONNELL, C. W., Foreman, Transmission Line Construction, Isthmian Canal Commission, Corozal, C. Z.; res, Birmingham, Ala.

CONNON, CHARLES ARTHUR, Operator, Pacific Light & Power Corp., Bodfish, Cal.

CORDIER, GABRIEL, Managing Director, Energie Electrique du Littoral Mediterraneen, 3 Rue Moncey, Paris IX, France.

FEEHAN, J. HARRY, JR., Property Foreman, Isthmian Canal Commission, Gatun, C. Z.

FENTON, MILLARD F., 4419 Ingalls St., San Diego, Calif.

LYMAN, VAN ALLEN, Power Plant Operator, Miraflores Generating Station, Corozal, C. Z.

ROOSEVELT, JOHN K., Engineer & Electrician in Charge of Isthmus Cables, Central & South American Tel. Co., Panama, Panama.

Total 12.

Applications for Election

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before August 30, 1914.

Barclay, R. H., Kansas City, Mo.
Bellman, J. J., New York, N. Y.
Brattle, W. P., Regina. Sask.
Briggs, L. E., E. Orange, N. J.
Davidson, J. F., Corozal, C. Z.
Du Bose, M., Lerida, Spain.
Fleming, A. P. M. (Member), Manchester, England.
Giersch, R. F., Jr., Lerida, Spain.
Hadley, F. E., Boston, Mass.
Heim, Henry. Bolinas, Cal.
Hodge, W. E., Springfield, Mass.
Hope, L. W., Eureka, Nev.
Jacobsen, H. W., Gatun, C. Z.
Lewis, L. W., Balboa, C. Z.
McEachron, K. B., Pittsfield, Mass.
Mullen, F. B., New York, N. Y.
Parker, S. R., Regina, Sask.
Southgate, H. M., (Member), Washington, D. C.
Spencer, C. G. (Member), Tocopilla, Chile.
Takata, N. I., Kobe, Japan.
Thompson, C. G., Empire, C. Z.
Williamson, R. W., Birmingham, Ala.

Student Enrolled July 10, 1914

Tapper, G. O., Lewis Institute.

The Schenectady Section

The Schenectady Section concluded, with a banquet on June 30, 1914, one of the most successful years which the Section has ever enjoyed.

The Section opened its season in the new Edison Club Building on November 5, 1913. Mr. E. W. Rice, president of the General Electric Company, delivered the opening address, and was followed by Dr. Charles P. Steinmetz, as honorary chairman, who spoke on "The Future Development of Electrical Engineering." In all, thirteen meetings have been held, at which scientists and engineers of prominence have lectured and taken part in the discussions.

The lecutres and meetings have been of an exceptionally high order, and great interest and enthusiasm has been manifested on the part of the members. The attendance at the meetings has been high, averaging 308, or about 47 per cent of the entire membership of the Section. Reports of all of the meetings have been published from time to time in the Institute PROCEEDINGS.

The membership of the Section to date includes 359 members of the national body who reside within the territory of the Schenectady Section and 303 local members whose dues are fully paid for the present season. The grand total is 662, or an increase of 20 over the previous year.

Because of the large number of young engineers who are yearly attracted to Schenectady, the local Section, in conjunction with the Edison Club, an organization exclusively for young electrical engineers, has this season instituted the custom of giving to first-year test men the privileges of membership for one-half the regular dues, the offer being open to all who join both organizations. Thirty-one men took advantage of this offer during the season.

In order to develop a spirit of good fellowship, and to bring about the mutual acquaintance of the younger and older men in the Section, three smokers have been held. One was given by the Schenectady Section with the Edison Club members as guests, one was held jointly by the two organizations, and the last one was given by the Edison Club, the members of the A. I. E. E. being invited guests.

The financial condition of the Schenectady Section is of the best, the Section being entirely self-supporting, with the exception of stationery, which is furnished by the national body. Printing and entertainment have called for an expenditure of about $370.00 during the season, and the balance left by last year's administration of the Section's affairs has been substantially increased.

Past Section Meetings

Chicago.—April 27, 1914. Subject: Industrial Power. Paper: "Power Problems in the Steel Business," by F. G. Gasche. Joint meeting with Electrical Section of the Western Society of Engineers. Attendance 75.

May 25, 1914. Paper: "Universal Use of Electricity on the Panama Canal," by D. P. Gaillard. Joint meeting with Electrical Section of the Western Society of Engineers. Attendance 80.

Detroit-Ann Arbor.—May 29, 1914, Adcraft Club. Subject: Illumination. Paper: "Factory Lighting," by George C. Keach. Attendance 65.

Fort Wayne.—June 16, 1914. Fort Wayne Commercial Club. Election of officers for the ensuing year as follows—chairman, L. D. Nordstrom; secretary-treasurer, J. J. A. Snook; executive committee, P. C. Morganthaler, J. J. Kline, C. I. Hall, and E. A. Wagner. Attendance 14.

Indianapolis-Lafayette. — May 22, 1914, Indianapolis. Inspection trip to the new power house of the Terre Haute, Indianapolis and Eastern Traction Company, Indianapolis, also to their old Washington Street plant. Attendance 100.

Los Angeles.—June 11, 1914. Election of officers for the ensuing year as follows—chairman, C. G. Pyle; secretary, Edward Woodbury; assistant secretary, R. H. Manahan; executive committee, J. A. Lighthipe, E. R. Northmore, Carl Johnson, and Julian Adams.

Milwaukee.—June 10, 1914, Colonial Room, Plankinton House. Illustrated lecture by Mr. Arthur Simon on "European Engineering Features." Election of officers for the ensuing year as follows—chairman, L. L. Tatum; secretary, W. J. Richards. Attendance 70.

Pittsburgh.—June 9, 1914, Oliver Building. Subject: Telephony. Papers: "Some Recent Improvements in Telephone Practise," by R. L. Snyder. Illustrated lecture by Mr. J. Gordon taditled "Spinners of Speech." Elec-

tion of officers for the ensuing year as follows—chairman, J. W. Welsh; secretary-treasurer, Charles R. Riker; directors, G. M. Eaton, B. C. Dennison, B. Wiley, E. R. Spencer, T. H. Schoepf, and Ray Dudley, the first four directors being continued from last year's board. Attendance 34.

Portland.—June 2, 1914, Hawthorne Building. The following officers were elected for the coming year—chairman, R. F. Monges; secretary and treasurer, Paul Lebenbaum; executive committee, G. P. Nock, L. T. Merwin, and L. R. Elder. Attendance 40.

Spokane.—May 15, 1914, Silver Grill. Papers: (1) "The Electric Motor," by G. S. Covey, (2) "Frequency-Changing Station of the Inland Empire System," by J. W. Hungate. Election of officers for ensuing year as follows—chairman, J. W. Hungate; vice-chairman, H. B. Peirce; secretary-treasurer, L. N. Rice; executive committee, J. B. Fisken, C. S. McCalla, S. E. Gates, and J. B. Ingersoll. Attendance 36.

Personal

Mr. A. H. Robbins, who was formerly electrical engineer with the Electric Light and Power Company of Abington and Rockland, N. Abington, Mass., is now consulting engineer, specializing in electrical engineering, for the General Engineering and Construction Company, 136 Liberty Street, New York.

Mr. J. R. Bibbins, engineer, of Chicago, has been engaged by the Law Department of the City of Pittsburgh in an advisory capacity in connection with proceedings for the improvement of local transportation conditions in that city. Mr. Bibbins is associated with Bion J. Arnold, of Chicago, and participated in a previous Arnold investigation in Pittsburgh. He also was resident engineer for the Arnold investigations of transit problems in Providence and San Francisco and of steam railroad terminal development in Chicago.

Obituary

Edward Leslie Farrar, sales agent of the Pittsburgh office of the General Electric Company, died in Pittsburgh July 7, 1914, of typhoid fever, after an illness of about ten days.

Mr. Farrar was in his thirty-first year, having been born in Norwell, Massachusetts, April 2, 1883. Mr. Farrar received his B.S. degree in 1905 at Tufts College, Medford, Massachusetts, graduating with honors. He then entered the employ of the General Electric Company in September, 1905, at the Pittsfield Works, and in June, 1906, was transferred to Schenectady. While in Schenectady Mr. Farrar followed special work in the engineering department, and in 1910 was transferred to the Pittsburgh office as sales agent.

Mr. Farrar was very highly respected and liked by his friends and business associates, and attained marked success in his field of endeavor. He was chairman of the Pittsburgh Section of the American Institute of Electrical Engineers during the year 1912-13, and was prominent in other engineering organizations.

Mr. Farrar was elected an Associate of the Institute on November 23, 1906, and was transferred to the grade of Member on December 13, 1912.

Library Accessions

The following accessions have been made to the Library of the Institute since the last acknowledgment.

Die Akkumulatoren, ihre Theorie, Herstellung, Behandlung, Verwendung mit Berucksichtigung der neueren Sammler. By W. Bermbach. Leipzig. 1905. (Purchase.)

Arc Lamps and Accessory Apparatus. By J. H. Johnson. New York, 1911. (Purchase.)

Die Beleuchtung von Eisenbahn-Personenwagen. Ed. 2. By Max Buttner. Berlin, 1912. (Purchase.)

Cours D'Electricité Theorique. By J. B. Pomey, Tome I. Paris, Gauthier-Villars, 1914. Price 13 fr. (Gift of publisher.)

This volume is based on lectures given by M. Pomey at the Ecole Supérieure des Postes et Télégraphes. Although theoretical in character, and mathematical in treatment, it is full of ultsres directly useful to the engineer. The second volume is in the press. W.P.C.

Electric Power Conductors Ed. 2. By Wm. A. DelMar. New York, 1913. (Purchase.)

Electrical Installations of Electric Light, Power, Traction and Industrial Electrical Machinery. vols. 1, 3, 4, 5. By Rankin Kennedy. v.p. 1902-03. (Purchase.)

Electro-Platers' Handbook. Ed. 5. By G. E. Bonney. London, n.d. (Purchase.)

Elektrische Lichteffekte. By Wilh. Biscan. Leipzig, 1909. (Purchase.)

Elektroanalytische Schnellmethoden. By A. Fischer (Die chemische analyse. By B. M. Margosches, Bd. IV-V). Stuttgart, 1908. (Purchase.)

Elektrochemische Zeitschrift. vol. 1, no. 1; vol. 6, nos. 10-12; vols. 7-8. Berlin, 1894, 1900-1902. (Purchase.)

Elektrotechnik in Einzeldarstellungen. By Gustav Benischke. (Pt. 1—Schutzvorrichtungen der Starkstromtechnik) Braunschweig, 1911. (Purchase.)

Franklin Institute. Index to Journal 1896-1905 Philadelphia, 1909. (Purchase.)

Hawkins Electrical Guide. Nos. 1-6. New York, Theo. Audel & Co., 1914. Price $1.00 each. (Gift of publisher.)

A series of questions and answers forming a progressive course of study on electricity and its applications. The volumes are in handy form, and are profusely illustrated. W. P. C.

High and Low Tension Switchgear Design. By A. G. Collis. New York, 1913. (Purchase.)

Journal de Physique. Table analytique et table par noms d'Auteurs. 1872-1901. Paris, 1902. (Purchase.)

Konstruktion und Prüfung der Elektrizitätszähler. By A. Königswerther. Ed. 2. Leipzig, Max Jänecke, 1914. Price 16 Mk. (Gift of publisher.)

This edition has been entirely rewritten, as was made necessary by the enormous improvements in electric meters. W. P. C.

Lifting the one hundred and thirty million pound Quebec Bridge. By H. F. Stratton. (Gift of Electric Controller & Mfg. Co.)

Modern Lightning Conductors: Ed. 2. By Killingworth Hedges. London, 1910. (Purchase.)

Molded Electrical Insulation and Plastics. By Emil Hemming. New York, 1914. (Purchase.)

Motor Control, as used in connection with Turret turning and gun elevating. By Andrew Olsson. New York, 1909. (Purchase.)

National Electric Light Association. Index to Proceedings of 32-35th conventions, 1909-1913. New York, 1914. (Gift of National Electric Light Association.)

National Fire Protection Association. Proceedings of 18th Annual Meeting, Chicago, May 1914. (Gift of Association.)

New York State. Public Service Commission. 1st District Report, vol. II, 1912. New York, 1913. (Exchange.)

New York (State) Public Service Commission, Second District, Annual Report 6th. vol. III. Albany, 1913. (Gift of Public Service Commission.)

Primary Battery Ignition. By C. Wadsworth, Jr. New York, 1912. (Purchase.)

Single-Phase Commutator Motors. By F. Creedy. New York, 1913. (Purchase.)

Telegraphen und Fernsprech-Technik in Einzeldarstellungen. By Th. Karrass. vol. XI. Braunschweig, 1914. (Purchase.)

Traité de Physique. Tome 4—L'energie electrique. By O. D. Chwolson. Paris, 1913. (Purchase.)

Gift of Frederick C. Bates

Abhandlungen und Berichte uber Technisches Schulwesen. Bd. I-IV. Berlin, 1910-1912.

New York Edison Company. Educational work arranged by the Association of Employees—Laboratory Practice 1913-1914. (5 books.)

——Syllabus of nine lectures on the Theory of Accounts, delivered by J. T. Madden.

Trade Catalogues

Delta Star Electric Co. Chicago, Ill. Bulletin No. 2. High Tension Equipment. Nov. 1912.

——No. 13. Steel tower substations complete with jib cranes and transfer table. May 1914.

Electric Storage Battery Co. Philadelphia, Pa. Bulletin No. 144. Fundamental Principles of the E. S. B. Axle Lighting system. May 1914.

General Electric Co. Schenectady N.Y. Bulletin 44010. High voltage D-C equipment of the Pittsburgh and Butler Street Railway. June 1914.

——44555. Straight air brake equipment with emergency feature. June 1914.

——44591. Motor driven air compressors—geared type. June 1914.

——47401. High voltage oil break switch for outdoor service type F, form K22. July 1914.

Push-Button control "Safety First" devices for industrial plants.

Hoppes Mfg. Co. Springfield, O. Catalog No. 50. The Hoppes exhaust steam feed water heaters, etc. 79 pp.

Meirowsky Bros. Jersey City, N.J. Price List No. 1. Mica. 16pp.

Standard Underground Cable Co. Pittsburgh, Pa. Bulletin 680-1. Steel tape armored cables. June 1914.

Wagner Electric Mfg. Co. St. Louis, Mo. Bulletin 105. Central Station Transformers. May 1914.

Western Electric Co. New York, N.Y. Interphones and accessories. 48pp.

United Engineering Society

Anuario de la América Latina. 1914. Barcelona. 1914. (Purchase.)

Caspar's Technical Dictionary English-German and German-English. Milwaukee, n. d. (Purchase.)

Celluloid, its raw material, manufacture, properties and uses. By Fr. Böckmann. London, 1907. (Purchase.)

Chapters on Paper Making. vols. 1-5. By Clayton Beadle. London, 1907-1909. (Purchase.)

Chemical German. By F. C. Phillips. Easton, Pa., 1913. (Purchase.)

Cortez Associated Mines. Report January 1910 to July 1912; October 1, 1913. Boston, n.d. (Gift of Olof Wenstrom.)

Design of Steel Mill Buildings and the Calculation of Stresses in Framed Structures. Ed. 3. By M. S. Ketchum. New York, 1913. (Purchase.)

Diccionario Técnico en Espanol, Francés. Inglés y Alemán. By D. Carlos Huelin y Arssu. Madrid, 1910. (Purchase.)

Manufacture of Leather. By H. G. Bennett. London, 1909. (Purchase.)

Municipal Index. Aug. 1912-Dec. 1913. New York, n.d. (Purchase.)

Orientation of Buildings or Planning for Sunlight. By William Atkinson. New York, 1912. (Purchase.)

Practical Handbook of Modern Library Cataloging. By W. W. Bishop. Baltimore, 1914. (Purchase.)

Reader of Scientific and Technical Spanish for Colleges and Technological Schools. By C. DeWitt Willcox. New York, 1913. (Purchase.)

A Text-Book of Physics. Ed. 3. Edited by A. W. Duff. Philadelphia, 1913. (Purchase.)

Thesaurus Dictionary of the English Language. By Francis A. March and F. A. March, Jr. 1910 Edition. Philadelphia, n.d. (Purchase.)

Treatise on Cement Specifications. By Jerome Cochran. New York, 1912. (Purchase.)

Treatise on the Law of Public Utilities Operating in Cities and Towns. By L. O. Pond. Indianapolis, 1913. (Purchase.)

Wahrscheinlichkeitsrechnung. Ed. 2. vols. 1-2. By Emanuel Czuber. Leipzig, 1908, 1910. (Purchase.)

OFFICERS AND BOARD OF DIRECTORS, 1914-1915

PRESIDENT.

(Term expires July 31, 1915.)

PAUL M. LINCOLN.

JUNIOR PAST-PRESIDENTS.

(Term expires July 31, 1915.)
RALPH D. MERSHON.

(Term expires July 31, 1916.)
C. O. MAILLOUX.

VICE-PRESIDENTS.

(Term expires July 31, 1915.)
J. A. LIGHTHIPE.
H. H. BARNES JR.
CHARLES E. SCRIBNER.

(Term expires July 31, 1916.)
F. S. HUNTING.
N. W. STORER.
FARLEY OSGOOD.

MANAGERS.

(Term expires July 31, 1915.)	(Term expires July 31, 1916.)	(Term expires July 31, 1917.)
COMFORT A. ADAMS.	H. A. LARDNER.	FREDERICK BEDELL.
J. FRANKLIN STEVENS.	B. A. BEHREND.	BANCROFT GHERARDI.
WILLIAM B. JACKSON.	PETER JUNKERSFELD.	A. S. McALLISTER.
WILLIAM McCLELLAN	L. T. ROBINSON.	JOHN H. FINNEY.

TREASURER.
GEORGE A. HAMILTON.

(Term expires July 31 1915.)

SECRETARY.
F. L. HUTCHINSON.

PAST-PRESIDENTS.—1884-1914.

*NORVIN GREEN, 1884-5-6.
*FRANKLIN L. POPE, 1886-7.
T. COMMERFORD MARTIN, 1887-8.
EDWARD WESTON, 1888-9.
ELIHU THOMSON, 1889-90.
*WILLIAM A. ANTHONY, 1890-91.
ALEXANDER GRAHAM BELL, 1891-2.
FRANK JULIAN SPRAGUE, 1892-3.
*EDWIN J. HOUSTON, 1893-4-5.
LOUIS DUNCAN, 1895-6-7.
FRANCIS BACON CROCKER, 1897-8.
A. E. KENNELLY, 1898-1900.
CARL HERING, 1900-1.
CHARLES P. STEINMETZ, 1901-2.
CHARLES F. SCOTT, 1902-3.
BION J. ARNOLD, 1903-4.
JOHN W. LIEB JR., 1904-5.
SCHUYLER SKAATS WHEELER, 1905-6.
SAMUEL SHELDON, 1906-7.
HENRY G. STOTT, 1907-8.
LOUIS A. FERGUSON, 1908-09.
LEWIS B. STILLWELL, 1909-10.
DUGALD C. JACKSON, 1910-11.
GANO DUNN, 1911-12.
RALPH D. MERSHON, 1912-13.
C. O. MAILLOUX, 1913-14.

*Deceased.

HONORARY SECRETARY.

RALPH W. POPE,
33 West 39th Street New York.

GENERAL COUNSEL.

PARKER and AARON,
52 Broadway, New York.

LIST OF SECTIONS

Revised to August 1, 1914.

Name and when Organized	Chairman	Secretary
Atlanta..........Jan. 19, '04	A. M. Schoen.	H. M. Keys, Southern Bell Tel. & Tel. Co., Atlanta, Ga
Baltimore........Dec. 16, '04	J. B. Whitehead.	L. M. Potts, Industrial Building, Baltimore, Md.
Boston..........Feb. 13, '03	Harold Pender	Harry F. Thomson, Massachusetts Institute of Technology, Boston, Mass.
Chicago.................. 1893	E. W. Allen.	W. J. Norton 112 W. Adams Street, Chicago, Ill.
Cleveland........Sept 27, '07	A. C. Eastwood.	R. E. Scovel, 1663 East 86th Street, Cleveland, Ohio.
Detroit-Ann Arbor.Jan. 13, '11	A. R. Sawyer.	Ray K Holland, Cornwell Building, Ann Arbor, Mich.
Fort Wayne......Aug. 14, '08	L. D. Nordstrom.	J. J. A. Snook, 1117 Fairfield Avenue, Ft. Wayne, Ind.
Indianapolis-Lafayette.Jan. 12, '12	O. S. More.	G. B. Schley, 908 Hume-Mansur Building, Indianapolis, Ind.
Ithaca...........Oct. 15, '02	E. L. Nichols.	George S. Macomber, Cornell University, Ithaca, N. Y.
Los Angeles......May 19, '08	C. G. Pyle.	Edward Woodbury Pacific Lt. & Pr. Company, Los Angeles, Cal.
Lynn............Aug. 22, '11	W. H. Pratt.	F. S. Hall, General Electric Co., Lynn, Mass.
Madison.........Jan. 8, '09	J. W. Shuster.	F. A. Kartak, Univ. of Wisconsin, Madison, Wis.
Mexico..........Dec. 13, '07		
Milwaukee.......Feb. 11, '10	L. L. Tatum.	W. J. Richards, National Brake and Electric Co. Milwaukee, Wis.
Minnesota.......Apr. 7, '02	Leo H. Cooper.	Emil Anderson, 1236 Plymouth Bldg., Minneapolis, Minn.
Panama.........Oct. 10, '13	Edward Schildhauer.	W. R. McCann, Isthmian Canal Commission, Culebra, Canal Zone.
Philadelphia......Feb. 18, '03	H. F. Sanville	W. F. James, 1115 North American Bldg.,Philadelphia,Pa.
Pittsburgh.......Oct. 13, '02	J. W. Welsh.	Charles R. Riker, Electric Journal, Pittsburgh, Pa.
Pittsfield........Mar. 25, '04	W. W. Lewis	M. E. Tressler, General Electric Company, Pittsfield, Mass.
Portland, Ore.....May 18, '09	R. F. Monges.	Paul Lebenbaum, 305 Beck Building, Portland, Ore.
St. Louis.........Jan. 14, '03	F. J. Bullivant.	A. McR. Harrelson, Emerson Electric Mfg. Co., St. Louis, Mo.
San Francisco...Dec. 23, '04	A. H. Griswold.	A. G. Jones, 819 Rialto Building, San Francisco, Cal.
Schenectady.....Jan. 26, '03	George H. Hill.	John R. Hewett, Gen. Elec. Co., Schenectady, N. Y.
Seattle..........Jan. 19, '04	S. C. Lindsay.	E. A. Loew, University of Washington, Seattle, Wash.
Spokane.........Feb. 14, '13	J. W. Hungate	L. N. Rice, Parsons Hotel, Spokane, Wash.
Toledo..........June 3, '07	George E. Kirk.	Max Neuber, Cohen, Freidlander & Martin, Toledo, O.
Toronto..........Sept. 30, '03	D. H. McDougall.	H. T. Case, Continental Life Bldg., Toronto, Ont.
Urbana..........Nov. 25, '02	I. W. Fisk.	P. S. Biegler, University of Illinois, Urbana, Ill.
Vancouver.......Aug. 22, '11	E. M. Breed.	L. G. Robinson, 1003 Holden Building, Vancouver, B. C.
Washington, D.C..Apr. 9, '03	C. B. Mirick.	C. A. Peterson. Treasury Department, Washington, D. C.

Total, 30

LIST OF BRANCHES

Revised to August 1, 1914.

Name and when Organized.	Chairman	Secretary
Agricultural and Mechanical College of Texas.....Nov. 12, '09	D. B. Pickens.	E. C. Rack, A. & M. College, College Station, Tex.
Arkansas, Univ. of......Mar. 25, '04	S. S. McGill.	M. B. Roys, Univ. of Arkansas, Fayetteville, Ark.
Armour Institute........Feb. 26, '04	E. L. Nelson.	T. C. Bolton, Armour Inst. Tech., Chicago, Ill.
Bucknell University.....May 17,'10	F. O. Schnure.	J. M. Hillman, Bucknell University, Lewisburg, Pa.
California, Univ. of......Feb. 9, '12	L. R. Chilcote,	E. S. Middaugh, University of California, Berkeley, Cal.
Cincinnati, Univ. of.....Apr. 10, '08	M. L. Harned	A. C. Perry, University of Cincinnati, Cincinnati, O.
Clemson Agricultural College..................Nov. 8, '12	F. J. Jervey.	F. H. McDonald, Clemson College, S. C.
Colorado State Agricultural College..........Feb. 11, '10	L. M. Klinefelter.	R. K. Havighorst. Colorado State Agricultural College, Fort Collins, Colo.
Colorado, Univ. of.......Dec. 16, 04	Philip S. Borden.	Charles S. Miller University of Colorado, Boulder, Colo.
Georgia School of Technology...........June 25, '14		
Highland Park College..Oct. 11, '12	E. B. Williams,	Ralph R. Chatterton, Highland Park College, Des Moines, Iowa.
Idaho, University of.....June 25, '14		
Iowa State College.....Apr. 15, '03	Earle G. Nichols.	F. A. Robbins, Iowa State College, Ames, Iowa.
Iowa, Univ. of.........May. 18, '09	J. H. Scanlon.	A. H. Ford, University of Iowa, Iowa City, Ia.
Kansas State Agr. Col...Jan. 10, '08	L. O'Brien.	W. C. Lane Kansas State Agric. Col., Manhattan, Kan.
Kansas, Univ. of.......Mar. 18, '08	H. C. Hansen.	L. M. Bocker, Univ. of Kansas, Lawrence, Kansas.
Kentucky State Univ. of.Oct. 14, '10	H. B. Hedges.	H. Tyler Watts, 315 East Maxwell Street, Lexington, Ky.
Lafayette College.......Apr. 5, '12	R. McManigal.	W. J. English, Jr., Lafayette College, Easton, Pa.
Lehigh University......Oct. 15, '02	N. F. Matheson.	F. C. Brockman, Lehigh University, S. Bethlehem, Pa.
Lewis Institute ....Nov. 8, '07	A. H. Fensholt,	Fred A. Rogers, Lewis Institute, Chicago, Ill.
Maine, Univ. of........Dec. 26, '06	C. M. Kelley.	E. L. Getchell, University of Maine, Orono, Maine.
Michigan, Univ. of......Mar. 25, '04	H. A. Enos.	H. W. Stubbs, University of Michigan, Ann Arbor, Mich.
Missouri, Univ. of......Jan. 10, '03	E. W. Kellogg	K. Atkinson University of Missouri, Columbia, Mo.
Montana State Col......May 21, '07	John M. Fiske.	J. A. Thaler, Montana State College, Bozeman, Mont.

LIST OF BRANCHES—Continued

Name and when Organized	Chairman	Secretary
Nebraska, Univ. of......Apr. 10, '08	Olin J. Ferguson.	V. L. Hollister, Station A, Lincoln, Nebraska
New Hampshire Col.....Feb. 19, '09		
North Carolina Col. of Agr. and Mech. Arts.......Feb. 11, '10	Wm.H.Browne,Jr.	James Fontaine, West Raleigh, N. C.
Ohio Northern Univ......Feb. 9, '12	A. B. Curtis,	W. F. Schott, Ohio Northern University, Ada, Ohio.
Ohio State Univ.........Dec. 20, '02	Leslie J. Harter.	Robert C. Schott, Ohio State Univ., Columbus, Ohio.
Oklahoma Agricultural and Mech. Col...........Oct. 13, '11	A. P. Little.	Quentin Graham, 118 Husband St., Stillwater, Okla.
Oklahoma, Univ. of......Oct. 11, '12	R. D. Evans.	L. J. Hibbard, Univ. of Oklahoma, Norman, Okla.
Oregon Agr. Col.........Mar. 24, '08	A. O. Manigold.	I. L. Olmstead, Oregon Agric. Col., Corvallis, Ore.
Penn State College......Dec. 20, '02	A. D. Shultz,	A. T. McNeile, State College, Pa.
Pittsburgh, University of. Feb. 26, '14	B. E. O'Hagan	George Hickman, University of Pittsburgh, Pittsburgh, Pa.
Purdue Univ............Jan. 26, '03	L. W. Spray.	R. E. Tafel, Purdue University, Lafayette, Ind.
Rensselaer Poly. Inst....Nov. 12, '09	W. J. Williams,	H. F. Wilson Rensselaer Poly. Institute, Troy, N. Y.
Rose Polytechnic Inst....Nov. 10, '11	Charles F. Harris.	Claude A. Lyon, 1331 Liberty Avenue, Terre Haute, Ind.
Rhode Island State Col..Mar. 14, '13	W. C. Miller.	P. M. Randall, Jr., Rhode Island State College, Kingston, R. I.
Stanford Univ...........Dec. 13, '07	G. L. Beaver.	H. J. Scholz, Stanford University, Cal.
Syracuse Univ...........Feb. 24, '05	W. P. Graham.	R. A. Porter, Syracuse University, Syracuse, N. Y.
Texas, Univ. of.........Feb. 14, '08	Joseph W. Ramsey,	J. A. Correll. University of Texas, Austin, Tex.
Throop College of Technology...............Oct. 14, '10	W. L. Newton,	A. W. Wells, Throop Poly. Institute, Pasadena, Cal.
Virginia, Univ. of........Feb. 9, '12	Walter S. Rodman	H. Anderson, Jr., 1022 West Main St., Charlottesville, Va.
Wash., State Col. of....Dec. 13, '07	M. K. Akers.	H. V. Carpenter, State Coll. of Wash., Pullman, Wash.
Washington Univ........Feb. 6, '04	R. D. Duncan, Jr.	C. C. Hardy, Washington University, St. Louis, Mo.
Washington, Univ. of...Dec. 13, '12	H. W. McRobbie.	B. B. Bessesen, Univ. of Washington, Seattle, Wash.
Worcester Poly. Inst.....Mar. 25, '04	Frank Aiken	A. B. R. Prouty, Worcester Poly. Inst., Worcester, Mass.
Yale University.........Oct. 03, 10	F. M. Doolittle	W. L. Kenly, New Haven, Conn.

Total, 48.

SECTION II

PROCEEDINGS

of the

American Institute

of

Electrical Engineers

Papers, Discussions and Reports

CONTENTS OF SECTION II

PAPERS TO BE PRESENTED AT SPOKANE, WASH., SEPT. 9-11, 1914.

PROCEEDINGS

OF THE

American Institute

OF

Electrical Engineers.

Published monthly by the A. I. E. E., at 33 W. 39th St., New York, under the supervision of

THE EDITING COMMITTEE

GEORGE R. METCALFE, Editor

Subscription. $10.00 per year for all countries to which the bulk rate of postage applies.

All other countries $12.00 per year.

Single copy $1.00.

Subscriptions must begin with January issue.

Changes of advertising copy should reach this office by the 15th of the month, for the issue of the following month

Vol XXXIII **September, 1914** No. 9

Pacific Coast Meeting, Spokane, September 9-11, 1914

The Pacific Coast Meeting, as previously announced, will be held in Spokane, Washington, September 9 to 11, 1914. The papers to be presented at this meeting have been printed in this and the previous issue of the PROCEEDINGS, and as we go to press advices received from the local committee in Spokane indicate that there will be an unusually large attendance at this meeting. The complete program for this meeting was printed in the August PROCEEDINGS.

A. I. E. E. Meeting in Philadelphia

Upon the request of the Philadelphia Section the Board of Directors has authorized an Institute meeting to be held in Philadelphia on Monday, October 12, 1914, under the auspices of the Philadelphia Section and the Committee on Use of Electricity in Marine Work. This committee announces that three papers have been promised for presentation at this meeting, as follows: "The Electrical Equipment of the Argentine Battleship *Moreno*", by H. A. Hornor, "Submarine Signaling", by Prof. R. A. Fessenden, and "Electrical Features of the U. S. Reclamation Service", by F. H. Newell.

Membership Campaign

The American Institute of Electrical Engineers expects to inaugurate an active campaign for new members. We hope every member will read the articles as they appear each month and do his part to "boost" the Institute. The following letter to President Lincoln gives our preliminary plan and the chairman will be glad to receive suggestions. Our efforts to secure new members, while active, must be such as to maintain the dignity of the Institute and promote all of its interests.

H. D. James,

Chairman Membership Committee.

Letter to President Lincoln dated Aug. 10, 1914.

"The writer has formulated a tentative program for securing new members. He proposes to discuss this program with the members of this committee, but before doing so, wishes to submit it to the Board of Directors for their information and for any suggestions or alterations which they may desire to make.

"The United States Census for 1910 shows a total of 135,519 electrical engineers and electricians in continental United States. Of this number, undoubtedly a great majority would not be available for membership in the Institute, but it is probable that some 25,000 of these would make good members for the Institute.

"Our colleges and universities have graduated about 14,000 electrical engineers during the last ten years. This is more than double the present enrolment of the Institute in the United States.

"The above statements show that there is ample material for us to work

upon, and the writer believes that our Institute should obtain a membership of at least 25,000 in the near future. To promote the campaign, the following outline is submitted.

"*First:* Have a pamphlet printed giving the reasons for joining the A. I. E. E., together with information for making application.

"*Second:* Have each Section and Branch appoint a committee on membership and organize a local campaign for new members. These committees should be followed up actively by the main committee.

"*Third:* Write a letter to each Section and Branch chairman to be presented at the first meeting this fall, outlining our campaign and as far as possible stimulating them to take an active part in obtaining new members.

"*Fourth:* Publish a paragraph in each PROCEEDINGS, bringing the campaign to the attention of all members, and emphasizing one reason in each issue for becoming a member of the Institute, also giving data as to new members elected, together with their geographical location.

"If possible, this monthly article should stimulate rivalry between various sections of the country, to obtain their proportionate increase in membership.

"*Fifth:* Endeavor to get in touch with local engineering organizations and active members in localities where we have no Section or Branch organization. This is the hardest territory to cover, and we will need the active co-operation of all Institute officers and committee men to help us in canvassing this unorganized territory.

"*Sixth:* Keep in close touch with the committee on local Sections, so that the organization of additional Sections may follow along with the membership campaign."

Attached is a list of electricians and electrical engineers by states, as given in the 1910 census, together with a list of the members of the A. I. E. E., as given by the 1914 Year Book.

ELECTRICIANS AND ELECTRICAL ENGINEERS IN THE UNITED STATES. DISTRIBUTED BY STATES.

	1910 U. S. Census	1914 Year Book
TOTAL	135,519	6359
Alabama	,139	36
Arizona	345	21
Arkansas	439	22
California	8,331	511
Colorado	1,020	65
Connecticut	2,017	102
Delaware	318	17
District of Columbia	969	74
Florida	535	10
Georgia	1,149	60
Idaho	554	22
Illinois	12,955	483
Indiana	3,589	108
Iowa	1,625	55
Kansas	1,393	20
Kentucky	1,314	24
Louisiana	1,004	10
Maine	1,042	22
Maryland	1,810	76
Massachusetts	7,602	498
Michigan	4,088	94
Minnesota	2,179	79
Mississippi	366	9
Missouri	4,254	159
Montana	751	40
Nebraska	1,018	29
Nevada	225	7
New Hampshire	619	13
New Jersey	6,740	288
New Mexico	179	8
New York	28,211	1709
North Carolina	641	39
North Dakota	192	1
Ohio	8,134	286
Oklahoma	914	17
Oregon	1,550	93
Pennsylvania	13,467	671
Rhode Island	1,014	27
South Carolina	479	19
South Dakota	272	11
Tennesse	1,107	22
Texas	2,232	66
Utah	904	62
Vermont	351	8
Virginia	1,492	54
Washington	3,159	129
West Virginia	1,191	25
Wisconsin	2,629	145
Wyoming	211	3
Alaska		2

Directors' Meeting, New York, August 11, 1914

The Board of Directors of the Institute held its first meeting for the administrative year which began August 1, in New York, on Tuesday, August 11, 1914, at 3:30 p.m.

There were present: President P. M. Lincoln, Pittsburgh, Pa.; Past-President C. O. Mailloux, New York; Vice-Presidents H. H. Barnes, Jr., New York, F. S. Hunting, Fort Wayne, Ind., N. W. Storer, Pittsburgh, Pa.; Managers C. A. Adams, Cambridge, Mass., William B. Jackson, Chicago, Ill., H. A. Lardner, San Francisco, Cal., L. T. Robinson, Schenectady, N. Y., Frederick Bedell, Ithaca, N. Y., Bancroft Gherardi, A. S. McAllister, New York; Treasurer George A. Hamilton, Elizabeth, N. J., and Secretary F. L. Hutchinson, New York.

President Lincoln announced his appointments on the various Institute committees for the present administrative year, as published elsewhere in this issue.

The Board elected from its own membership the following members to serve upon the Edison Medal Committee for two years to fill the places of members whose terms had expired: C. O. Mailloux, L. T. Robinson, Charles E. Scribner. Mr. A. S. McAllister was elected for the term of one year to fill a vacancy.

The Board also confirmed the appointment by the President of the following members of the Edison Medal Committee for five years: Charles F. Brush, William Stanley, and N. W. Storer.

The following Local Honorary Secretaries were reappointed for a term of two years: Robert Julian Scott, Christ Church, New Zealand; Henry Graftio, St. Petersburg, Russia; A. S. Garfield, Paris, France.

At his request the President was authorized to appoint a new committee on the use of electricity in the iron and steel industry, in order that the Institute could provide for its members interested in this important branch of electrical engineering adequate opportunity for the presentation of papers and discussions relating to the subject. The appointment of this committee will be announced later.

The action of the Finance Committee in approving for payment monthly bills amounting to $6,859.73 was ratified.

The report of the Board of Examiners of its meeting held on August 6 was accepted and the actions taken by the Board were approved.

Upon recommendation of the Board of Examiners, the Board of Directors transferred five members of the Institute to the grade of Member, and six to the grade of Fellow, and elected three applicants to the grade of Member, 37 applicants as Associates, and ordered the enrolment of six students, in accordance with the lists printed in this issue of the PROCEEDINGS.

Upon the request of the Philadelphia Section and the recommendation of the Meetings and Papers Committee an Institute meeting was authorized to be held in Philadelphia, Pa., on October 12, 1914.

Upon the recommendation of the Section delegates present at the Detroit Convention, Section 60 of the Institute by-laws, fixing the amount of financial support to which each Section is entitled from the Institute, was amended so as to increase the amount available for the work of each Section by fifty dollars. Under the by-law the amount available previously was determined as follows: (a) Fifty dollars for each Section regardless of the number of members in its territory; (b) One dollar and a quarter for each member in a Section's territory of 60 miles from its headquarters. The amendment increased the flat appropriation (a) of fifty dollars for each Section to one hundred dollars. This action was taken chiefly for the benefit of the smaller Sections whose membership is not sufficient to provide adequate funds

to meet the expenses of holding meetings.

It was voted to hold the usual midwinter convention in New York during the coming winter.

A considerable amount of other business was transacted by the Board, reference to which will be found under appropriate headings in this and future issues of the PROCEEDINGS.

I. E. S Annual Convention

The eighth annual convention of the Illuminating Engineering Society will be held at Cleveland, Ohio, September 21 to 25, 1914. The headquarters of the convention will be the Hollenden Hotel. The following list of papers to be presented during the convention gives a good idea of the scope of the technical sessions:

" Factory Lighting," by Hogue and Dicker.

" Some Experiments with the Ferree Test for Eye Fatigue," by J. R. Cravath.

"Planning for Daylight and Sunlight in Buildings," by Marks and Woodwell.

" Notes on the Ulbricht Integrating Sphere and Arc Lamp Photometry," by H. K. Chaney.

"Effect of Room Dimensions on Efficiency of Lighting Systems," by Ward Harrison.

" Relation of Light to the Critical Inspection of Documents," by A. S. Osborne.

" Experiments with Colored Absorbing Solutions for Use in Heterochromatic Photometry," by H. E. Ives and E. F. Kingsbury.

" A New Standard Light Source," by L. A. Jones.

" Artificial Daylight—Its Production and Use," by M. Luckiesh and F. E. Cady.

" Characteristics of Gas - Filled Lamps," by G. M. J. Mackay.

" A Transmission and Absorbing Photometer for Small Areas," by Nutting and Jones.

" Recent Improvements in Gas Lamps," by a Welsbach representative.

" Illumination of Light Shafts," by C. H. Sharp.

" Portable Mine Lamp," by H. H. Clark.

" Some Recent Experiments on Vision in Animals," by H. M. Johnson.

" Light Filters for Use in Photometry," by C. E. K. Moes.

" The Locomotive Headlight," by J. L. Minick.

" Present Practise in Machine-Shop Lighting," by Powell and Harrington.

" The Development of Daylight," by E. J. Brady.

" Lighting of the Home," by a representative of The Duquense Light Company.

" Lighting of a Carpet Mill," by Rose and Ockley.

" Color Variation in Illuminants," by Jones and Nutting.

" Reflection Standards," by Nutting and Jones.

" Physiological Effects of Light on the Body," by E. C. Titus.

In addition to the program of papers, the general convention committee has arranged a number of entertainment features and trips to points of interest in and about Cleveland for both ladies and gentlemen.

International Engineering Congress, 1915

The Committee on Local Affairs of the International Engineering Congress, San Francisco, September 20th to 25th, 1915, has secured an option on one hundred rooms in the three leading hotels of San Francisco, distributed as follows:

40 rooms each, at the Palace and St. Francis.

20 rooms at the Fairmount.

Rates applying will be $7.00 for the court rooms, occupied by two people, or $10.00 per day for outside rooms occupied by two people. The option on these rooms expires on October 17 of this year.

In making reservations, the hotels require a deposit of 50 per cent of the rate per day for the period of the reservation. For the convenience of members

of the Congress, the Executive Office of the Committee of Management, in San Francisco, will undertake to act for members who desire to make reservations now, and if draft or check is made payable and mailed to W. A. Cattell, Treasurer, 417 Foxcroft Building, San Francisco, receipts will be returned from the hotel company for the amount.

At a later date, the committee contemplates issuing a circular to the membership of the congress, asking their wishes regarding hotel accommodations, and in case reservations are not desired in any one of the three hotels mentioned above, the committee will make reservations in other hotels in accordance with the indicated desires of members.

The membership of the Institute is reminded that the above-mentioned congress is scheduled for the week following the International Electrical Congress, which is scheduled to begin on September 13, 1915.

Recommended for Transfer to the Grade of Member, August 6, 1914

The Board of Examiners, at its regular monthly meeting on August 6, 1914, recommended the following Associates for transfer to the grade of Member. Any objection to these transfers should be filed at once with the Secretary.

MURPHY, PATRICK J., Electrical Engineer, Ford, Bacon & Davis, New York, N. Y.

MOURADIAN, H., Engineer of Transmission and Protection, Bell Telephone Co. of Penna., Philadelphia, Pa.

PILLSBURY, CHARLES L., Consulting Engineer, Minneapolis, Minn.

Transferred to the Grade of Fellow August 11, 1914

HARTMANN, FRANCIS M., Professor of Electrical and Mechanical Engineering, Cooper Union, New York, N. Y.

HENDERSON, CLARK TRAVIS, Electrical and Mechanical Engineer, Cutler-Hammer Mfg. Co., Milwaukee, Wis.

STILL, ALFRED, Professor of Electrical Engineering, Purdue University, Lafayette, Ind.

SYKES, WILFRED, Electrical Engineer, Westinghouse Electrical and Mfg. Co. East Pittsburgh, Pa.

UNDERHILL, CHARLES R., Chief Electrical Engineer, Acme Wire Co., New Haven, Conn.

WELSH, JAMES W., Electrical Engineer and Traffic Agent, Pittsburg Railways Co., Pittsburgh, Pa.

Transferred to the Grade of Member August 11, 1914

BIBBINS, JAMES ROWLAND, Resident Engineer, Bion J. Arnold,Chicago, Ill.

DAVIES, CHARLES EDWARD, Superintendent of Equipment, Great Northwestern Telegraph Co., Ottawa, Ont.

DEARBORN, RICHARD H., Head of Dept. of Elec. Eng., University of Oregon; Electrical Engineer for Railroad Commission of Oregon, Eugene, Ore.

HULL, CLARENCE S., Foreman, Standardizing Laboratory, General Electric Co., San Francisco, Cal.

LINDSAY, SHERWOOD C., Electrical Engineer, Puget Sound Traction, Light & Power Co., Seattle, Wash.

Members Elected August 11, 1914

GRAY, HENRY L., Consulting Engineer, Seattle, Wash.

MOORE, ALLEN HENRY, Chairman, Standardizing Committee, General Electric Co., Schenectady, N. Y.

RIDER, O. O., Assistant to General Superintendent, Public Service Electric Co. Of Northern Illinois, Chicago Ill.

Associates Elected August 11, 1914

ADLER, LAWRENCE, Wireman, Panama Canal, Corozal, C. Z.

BECK, OTTO C., Electrician, Pennsylvania Water Power Co., Holtwood, Pa.; res., 2853 Woodbrook Ave., Baltimore, Md.

BERNHARD, JOHN H., Water Transportation and Ship Building; res., 19 Rosa Park, New Orleans, La.

CHASE, STACY REEVES, Electrical Engineering Dept., Pennsylvania Railroad Co.; res., 1419 Twelfth St., Altoona, Pa.

CLARK, BEN. W., Chief Electrical Inspector, Edison Illuminating Co., 56 E. Atwater St., Detroit, Mich.

DEAN, GEORGE REINALD, Professor of Mathematics, School of Mines, University of Missouri, Rolla, Mo.

ENDRESS, WILLIAM F., Captain, Corps of Engineers, U. S. Army, Gatun, C.Z.

GARDNER, HOWARD S., Chicago Branch Manager, Willard Storage Battery Co., 2241 S. Michigan Ave., Chicago, Ill.

GROSS, BENJAMIN, Electrical Engineer, L. K. Comstock & Co., 30 Church St.; res., 129 E. 7th St., New York, N.Y.

HERZSCH, F. H., Sales Engineer, Westinghouse Electric & Mfg. Co.; res., 1303 Michigan Ave., Cincinnati, O.

HULL, SEYMOUR P., Electric Light & Power Plant, Topeka, Ind.

IZHUROFF, BASIL A., St. Petersburg, Russia.

KLEENE, WALTER F., Draftsman, Panama Canal, Balboa, C. Z.; res., 2211 Gurling St., Chicago, Ill.

LINDSTROM, ALBERT S., Superintendent, Electrical and Machinery Exhibits, Panama-Pacific International Exposition; res., 675 9th Ave., San Francisco, Cal.

MALUQUER I NICOLAU, JOSEF, Electrical Engineer, Ebro Irrigation & Power Co., Ltd., Barcelona, Spain.

McCOY, THOMAS E., Line Foreman, Panama Canal, Corozal, C. Z.

MOFFET, FRANK V., JR., Electrical Engineer and Contractor, Kelowna, B. C.

NEWTON, ARTHUR H., Electrical Engineer, Insular Bureau, U. S. War Department, Philippine Islands.

PEARCE, WALTER C., Superintendent, Syracuse Lighting Co.; res., 110 Judson St., Syracuse, N. Y.

PONTECORVO, GIULIO, Electrical Engineer, Westinghouse Electric & Mfg. Co., E. Pittsburgh, Pa.

PRITCHARD, HARRY TURNBULL, Superintendent of Construction, Sanitary District of Chicago; res., 335 W. 64th St., Chicago, Ill.

REMER, GEORGE D., Superintendent, Light & Power Plant, Dows, Ia.

ROBERTS, CHARLES WILLIAM, Electrical Foreman, Panama Canal, Gatun, C.Z.

ROBERTS, GEORGE R. W., General Inspector. Portland Eugene & Eastern R. R., 305 Beck Bldg., Portland; res., Beaverton, Ore.

SAUNDERS, JOHN E., Electrical Engineer, Union Switch & Signal Co., Swissvale; res., 111 Maple Ave., Edgewood, Pittsburg, Pa.

SCHUTT, G. H., Wireman, Panama Canal, Miraflores; res., Pedro Miguel, C. Z.

SEAVER, HORACE, Wireman, Testing Dept., Panama Canal, Corozal, C. Z.

SHIPLEY, G. A., Sub-Foreman on Interior Electrical Construction, Southern California Edison Co.; res., 255 E. Adams St., Los Angeles, Cal.

SPRUANCE, FREDERICK D., Wireman, Panama Canal, Corozal, C. Z.

STEINER, CHARLES W., Electrical Engineer, Wagner Electric Mfg. Co., 6400 Plymouth Ave., St. Louis, Mo.

STEPHENS, W. H., Electrical Engineering Dept., Northwestern Electric Co.; res., 453 12th St. North, Portland, Ore.

SWIFT, FRANK H., Engineer, Powell River Co. Ltd., Powell River, B. C.

THOMPSON, JOSEPH S., President, Pacific Electric Mfg. Co., 80 Tehama St., San Francisco, Cal.

THRALL, CHARLES H., President, Charles H. Thrall Electrical Construction Co., Havana, Cuba.

VANIMAN, ROY L., Assistant to Consulting Engineer, Hotel Dunsmuir, Vancouver, B. C.

WILLIAMS, J. F., Mechanical Engineer, Thompson Starret Co., via Colon and Antofogosta, Chuquicamata, Chile, S. A.

WRIGHT, JOHN DAVID, Electrical Engineer, Industrial Control Dept., General Electric Co., Schenectady, N. Y.

Total 37.

Applications for Election

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before September 30, 1914.

Beebe, J. C., Richfield, Idaho.
Blair, C. A., Los Angeles, Cal.
Burnett, J. J., New York, N. Y.
Feuchter, R. J., Cleveland, O.
Hamon, C. A., E. Pittsburgh, Pa.
Jealous, A. R., Newark, N. J.
Kawakita, Y., Osaka, Japan
Komuro, T., Yokohama, Japan
Lloyd, A. M., Cleveland, O.
Lyon, J. D. (Member), Cincinnati, O.
Markham, C. W., Balboa Heights, C. Z.
McRae, D. M., Winnipeg, Man.
Miller, A. R., Cleveland, O.
Moulton, S. A., Portland, Me.
Shiraki, K., Tokyo, Japan
Shirley, A. A., Schenectady, N. Y.
Stratemeyer, E. A., Cincinnati, O.
Vowell, C., Napier, N. Z.
Waldron, G. T., Peekskill, N. Y.
Westerwick, A., Los Angeles, Cal.
Williams, R. A., Los Angeles, Cal.

Students Enrolled August 11, 1914

6689 Boone, F. P., Highland Park Coll.
6690 Fiske, J. M., Montana State Coll.
6691 Rogers, E. B., Wentworth Inst.
6692 Scanlon, J. L., Univ. of Iowa
6693 Sprague, W. A., Highland Park Coll.
6694 Timmerman, L. B., Cornell Univ.

Past Section Meetings

Chicago.—June 10, 1914. Subject; Illumination. Papers; (1) "The Design of Illuminated Signs", by A. H. Ford; (2) "Chicago Street Lighting", by Mr. Matheny. Joint meeting with Illuminating Engineering Society. Election of officers for the ensuing year as follows—Chairman, E. W. Allen; Secretary, W. J. Norton. Attendance 60.

Panama.—July 12, 1914, Pedro Miguel Locks. Paper; "Hydraulics of the Locks", by R. H. Whitehead. Demonstration of actual operation of the gates. Attendance 85.

August 2, 1914.—Election of officers for the ensuing year as follows—Chairman, Hartley Rowe; vice-chairman, George A. Balling; secretary-treasurer, Clayton J. Engree; executive committee, F. C. Clark, A. B. Kratz, and Wm. H. Fenley.

Schenectady.—June 30, Mohawk Golf Club. Annual banquet of Section. Addresses were given by President-elect P. M. Lincoln, and Messrs. G. H. Hill, W. B. Potter, D. B. Rushmore, G. E. Emmons, A. W. Clark, and Lindsay. The banquet was followed by vocal entertainment. Attendance 85.

Past Branch Meetings

Highland Park College.—May 20, 1914. Main College Building. Subject; High Tension Transmission. Short addresses as follows; "The Design of High Tension Transmission Lines", by John Gailunar, and "The Grounding of High Tension Lines", by Earl Wetzel. Attendance 16. June 18, 1914, College Inn. Informal banquet presided over by Dean A. Shane. Attendance 16.

July 9, 1914, Main College Building. Address by Mr. W. B. Zuker on "Electrochemistry." Election of officers for the ensuing year as follows—chairman, Clyde Prussman; vice-chairman, H. E. Steadman; secretary-treasurer, R. R. Chatterton; executive committee, C. F.

Wright, Wayne Sprague, and E. E. Gould. Attendance 29.

Library Accessions

The fol owing accessions have been made to the Libr ry of the Institute since the last acknowledgment.

Die Akkumulatoren. Ed. 4. By Karl Elbs. Leipzig, 1908. (Purchase.)

Die Akkumulatoren und galvanischen Elemente. By L. Lucas. Hannover, 1906. (Purchase.)

Bau, Betrieb und Instandhaltung Elektrischer Anlagen. Ed. 2. By Franz Grunwald. Halle a.S., 1912. (Purchase.)

Bau und Instandhal.ung der Oberleitungen elektrischer Bahnen. By P. Poschenrieder. München, 1904. (Purchase.)

Die Berechnung elektrischer Leitungen insbesondere der Gleichstrom-Verteilungsnetze. Ed. 2. By E. Rohrbeck. Leipzig, 1909. (Purchase.)

Berechnung und Konstruktion elektrischer Schaltapparate. By R. Edler. Hannover, 1909. (Purchase.)

Boston-Gas & Electric Light Commissioners. Annual Report of the Board. 29th. Boston, 1914. (Gift of Gas & Electric Light Commissioners.)

Canterbury College—School of Engineering. Catalogue. Christchurch, 1914. (Gift of Canterbury.) College.

Cyanamid, manufacture, chemistry and uses. By Edw. J. Pranke. Easton, 1913. (Purchase.)

Discovery and Invention. By Alexander Graham Bell. (Reprinted from National Geographic Magazine, June 1914.) Washington, 1914. (Gift of author.)

Der Drehstrommotor als Eisenbahnmotor. By Wilhelm Kubler. Leipzig, n.d. (Purchase.)

Der Edisonakkumulator. By Meno Kammerhoff. Berlin, 1910. (Purchase.)

Die Einrichtung elektrischer Beleuchtungsanlagen für Wechsel und Drehstrombetrieb. By Richard Bauch. Leipzig, 1905. (Purchase.)

Electric Vehicle Association of America. Papers, Reports and Discussions 4th Annual Convention. 1913. New York, 1913. (Gift of Association.)

Elektrische Schaltanlagen und Apparate. By F. Niethammer Stuttgart, 1905. (Purchase.)

Die Elektrischen Bahnen und ihre Betriebsmittel. By Herbert Kyser. Braunschweig, 1907. (Purchase.)

Die elektrischen Bahnsysteme der Gegenwart. By F. Biethammer. Zurich, 1905. (Purchase.)

Die Elektrizität auf den Dampfschiffen. Ed. 3. By E. Bohnenstengel. Hannover, 1907. (Purchase.)

Die Elektrizität und ihre Technik. Ed. 6-7. 5 pts. Leipzig, 1906. (Purchase.)

Elektromechanische Konstruktionselemente. Skizzen pts. 2, 3, 5, 6. By G. Klingenberg. Berlin, 1902, 1905. (Purchase.)

Freileitungsbau Ortsnetzbau. By F. Kapper. Munchen, 1913. (Purchase.)

Geschichte des Elektroeisens. By Oswald Meyer. Berlin, 1914. (Purchase.)

Handbuch der Elektrizität und des Magnetismus. Band II: pt. 2. By L. Graetz. Leipzig, 1914. (Purchase.)

Handbuch der Elektrochemie. Ed. 2. By Felix B. Ahrens. Stuttgart, 1903. (Purchase.)

Handbuch für den Bau und die Instandhaltung der Oberleitungsanlagen elektrischer Bahnen. By Arthur Ertel. Leipzig, n.d. (Purchase.)

Hilfsbuch für die Montage elektrischer Leitungen zu Beleuchtungszwecken. Ed. 2. By A. Peschel. Leipzig, 1903. (Purchase.)

Instruccao Technica nos Estados Unidos. By V. de Vivaldi-Coaracy. 1913. Porto Alegre, 1914. (Gift.)

International Electrotechnical Commission. Comptes Rendus des séances de la Reunion tenue à Berlin, Sept. 1913. Londres, 1914. (Gift of Commission.)

Iowa Engineering Society. Proceedings of the 26th Annual Meeting, 1914. Iowa City, 1914. (Gift of Iowa Engineering Society.)

Die Isolationsmessung und Fehler ortsbestimmung in elektrischen Starkstromanlagen. By Paul Stern Hannover, 1908. (Purchase.)

Messapparate und Messmethoden. Ed. 3 By W. Knobloch Leipzig, 1913. (Purchase.)

Die Metalldampflampen mit besonderer Berücksichtigung der Quecksilberdampflampen. By Otto Vogel. Leipzig, 1907. (Purchase.)

New Hampshire. Public Service Commission. Reports and Orders. vol. IV, nos. 1-3. n.p. 1913-1914. (Gift of Public Service Commission of New Hampshire.)

Oberbau und Betriebsmittel der Schmalspurbahnen. Ed. 2. By E. Dietrich. Berlin, 1914. (Purchase.)

Physical Society of London. Report on Radiation and the Quantum-theory. London, 1914. (Exchange.)

Praktische Anleitung für Bau, Behandlung und Reparatur von transportabl. Akkumulatoren. Ed. 3. By Alfred Luscher. Dresden, n.d. (Purchase.)

Railway Library, 1913. By Slason Thompson. Chicago, 1914. (Gift of author.)

Die Revision elektrischer Starkstromanlagen. Ed. 2. By Paul Stern. Leipzig, 1907. (Purchase.)

Royal Society of London. Catalogue of Scientific Papers 1800-1900. Subject Index—Physics. Volume III, pts. 1-2. Cambridge, 1912, 1914. (Gift of E.D. Adams.)

Safety First, from the Street Railway Operating Side. delivered at the 10th Annual Convention of The Southwestern Electrical & Gas Association. May 20-23, 1914. N.p. n.d. (Gift of Association.)

Schaltungen fur elektrische Beleuchtungs und Maschinen Anlagen. Ed. 2. By L. Lerch. Hannover, 1913. (Purchase.)

Schaltungsbuch für Elektr. Lichtanlagen. Ed. 2. By Bruno Thierbach. Leipzig, 1912. (Purchase.)

Schaltungsbuch für elektrische Anlagen. Ed. 2. By W. Weiler Leipzig, 1911. (Purchase.)

Schaltungsbuch für Schwachstrom-Anlagen. Ed. 20. By Max Lindner. Leipzig, 1913. (Purchase.)

Société Internationale des Electriciens. Table Générale des Matières de la Bulletin. 2d. Ser. 1901-1910. Paris, 1914. (Exchange.)

Standardization Rules of the American Institute of Electrical Engineers as approved by the Board of Directors, July 10, 1914 to take effect Dec. 1, 1914. New York, 1914. (Gift of General Electric Company.)

A Few Statistics Regarding the Use of Electricity on the Witwatersrand. n.p. 1914. (Gift of South African Institute of Electrical Engineers.)

Stromverteilungssysteme und Berechnung elektrischer Leitungen. By Phil. Hafner. Hannover, 1906. (Purchase.)

Theorie, Berechnung, Konstruktion und Wirkung der Olschalter. By R. Edler. Leipzig, 1913. (Purchase.)

Theorie der Wechselströme. By Alfred Fraenckel. Berlin, 1914. (Purchase.)

Transformatoren für Wechselstrom und Drehstrom. Ed. 3. By Gisbert Kapp. Berlin, 1907. (Purchase.

Die Umformer. By N. O. Lifschitz. Leipzig, 1908. (Purchase.)

Untersuchung eines Zugmagneten für Gleichstrom. By Karl Euler. Berlin, 1911. (Purchase.)

J. G. White & Company, Ltd. Report and Balance Sheet 14th, 1914. London, 1914. (Gift of J. G. White & Company.)

Die Wirkungsweise, Berechnung und Konstruktion der Gleichstrom-Dynamomaschinen und Motoren. Ed. 4. By Georg Schmidt-Ulm. Leipzig, 1909. (Purchase.)

Trade Catalogues

Allgemeine Elektricitäts-Gesellschaft. Der elektrische Betrieb von Wasserwerken Kanalisations und Entwasserungsanlagen. 24pp.

——Gusseisernes Installationsmaterial für Eisenbahnwerkstätten. 16pp.

——Hauswasserpumpen mit selbsttätigem elektrischen Antrieb. May 1914.

——Hochspannungskabel und Hochspannungs-Kraftübertragungen. May 1914.

——Registrierende Messinstrumente. Form G. 15pp.

——Tisch und Wandring Ventilatoren.

——Brennholz Kreissäge für die Landwirtschaft.

——Druckregler. May 1914.

Burdett-Rowntree Mfg. Co. New York City.
Elevator safeguards. 23pp.
Electric Dumb Waiter Service. 121pp.

Electric Storage Battery Co. Philadelphia, Pa.
"Chloride Accumulator" for fire alarm signal, telegraph and automatic time clocks Section A-1. 1914.
"Exide" charging system for garages. 9pp.
Bulletin 147. The "Ironclad-Exide" battery for yachts and power boats. June 1914.

Esterline Co. Indianapolis, Ind.
Catalog no. 321. Esterline Graphic Efficiency Instruments Model EB meters.

Goldschmidt Thermit Co. New York City.
Reactions. 2d Quarter. 1914.

Granger, A. D. Co. New York City.
Bull. no. 2. "Oswego" Internally Fired Water Tube Boilers. 1914.

Heine Safety Boiler Co. St. Louis, Mo.
Boiler Logic. 28pp.
Superheater Logic. 11pp.
Large Heine Boilers. 4pp.

Koehring Machine Co. Milwaukee, Wis.
Koehring Mixer. June-July, 1914.

Sangamo Electric Co. Springfield, Ill.
Bull. no. 37. Sangamo meters. Feb. 1914.

Sprague Electric Works. New York City.
Bull. no. 48901. Electric winches and winding drums.

Titan Storage Battery Co. Newark, N.J.
Titan Storage batteries. 30pp.

Wagner Electric Mfg. Co. St. Louis, Mo.
Bull. 105. Central Station Transformers. May 1914.

Western Electric Co. New York City.
The Making of the Voice Highways. Descriptive of the manufacture of lead covered telephone cable.

United Engineering Society

Handbuch der Ziegeleitechnik. By R. Weber. Berlin, 1914. (Purchase.)

International Congress of Applied Chemistry (9th) Preliminary announcement, July 26-Aug. 8, 1915. St. Petersburg. (Gift of Geo. F. Kunz.)

Key to the Architects of Greater New York. 1914. New York, 1914. (Purchase.)

Lockwood's Directory of the Paper, Stationery and Allied Trades. 39th Ed. 1914. New York, 1914. (Purchase.)

Manufacture of Lubricants, Shoe Polishes and Leather Dressings. By Richard Brunner, translated from the 6th German edition by Chas. Salter. London, 1906. (Purchase.)

Map of the Northern Peaks of the Great Range White Mountains, N. H. By Louis F. Cutter 1914. (Gift of author.)

Modern Flax, Hemp, and Jute Spinning and Twisting. By H. R. Carter. London, 1907. (Purchase.)

Moody's Manual of Railroads and Corporation Securities. Vol. 2. Industrial and Public Utility Section. New York, 1914. (Purchase.)

New York Times Index. Vol. II, April-June, 1914. New York, 1914. (Purchase.)

Paving and Municipal Engineering. vols. 1-21, 24-31. Indianapolis, 1890-1901, 1903-1906. (Purchase.)

Power-loom Weaving. By Anton Gruner, translated by Chas. Salter. London, 1900. (Purchase.)

Practical Paper-making. Ed. 2. By George Clapperton. London, 1907. (Purchase.)

Ramie (Rhea) China Grass. By Herbert A. Carter. London, 1910. (Purchase.)

Rubber, its sources, cultivation and preparation. By Harold Brown. London, 1914. (Purchase.)

Space Occupied by Water Tube Boilers. By C. R. D. Meier. (Paper read before Associated Engineering Societies, Apr. 30, 1913.) St. Louis, n.d. (Gift of Heine Safety Boiler Co.)

Superheating. By C. R. D. Meier (Reprinted from Journal of Engineers Society of Pa.) St. Louis, N.d. (Gift of Heine Safety Boiler Co.)

U. S. Post Office Department. Specification for the Construction of Steel Full Postal Cars, and fixtures therein. v.d. (Gift.)

Utilisation of Wood-waste. By Ernst Hubbard, translated from the German by M. J. Salter. London, 1902. (Purchase.)

Wood Products, distillates and extracts. By P. Dumesny and J. Noyer London, 1908. (Purchase.)

OFFICERS AND BOARD OF DIRECTORS, 1914-1915

PRESIDENT.

(Term expires July 31, 1915.)

PAUL M. LINCOLN.

JUNIOR PAST-PRESIDENTS.

(Term expires July 31, 1915.)	(Term expires July 31, 1916.)
RALPH D. MERSHON.	C. O. MAILLOUX.

VICE-PRESIDENTS.

(Term expires July 31, 1915.)	(Term expires July 31, 1916.)
J. A. LIGHTHIPE.	F. S. HUNTING.
H. H. BARNES JR.	N. W. STORER.
CHARLES E. SCRIBNER.	FARLEY OSGOOD.

MANAGERS.

(Term expires July 31, 1915.)	(Term expires July 31, 1916.)	(Term expires July 31, 1917.)
COMFORT A. ADAMS.	H. A. LARDNER.	FREDERICK BEDELL.
J. FRANKLIN STEVENS.	B. A. BEHREND.	BANCROFT GHERARDI.
WILLIAM B. JACKSON.	PETER JUNKERSFELD.	A. S. McALLISTER.
WILLIAM McCLELLAN	L. T. ROBINSON.	JOHN H. FINNEY.

TREASURER.	(Term expires July 31 1915.)	**SECRETARY.**
GEORGE A. HAMILTON.		F. L. HUTCHINSON.

PAST-PRESIDENTS.—1884-1914.

*NORVIN GREEN, 1884-5-6.
*FRANKLIN L. POPE, 1886-7.
T. COMMERFORD MARTIN, 1887-8.
EDWARD WESTON, 1888-9.
ELIHU THOMSON, 1889-90.
*WILLIAM A. ANTHONY, 1890-91.
ALEXANDER GRAHAM BELL, 1891-2.
FRANK JULIAN SPRAGUE, 1892-3.
*EDWIN J. HOUSTON, 1893-4-5.
LOUIS DUNCAN, 1895-6-7.
FRANCIS BACON CROCKER, 1897-8.
A. E. KENNELLY, 1898-1900.
CARL HERING, 1900-1.
CHARLES P. STEINMETZ, 1901-2.
CHARLES F. SCOTT, 1902-3.
BION J. ARNOLD, 1903-4.
JOHN W. LIEB Jr., 1904-5.
SCHUYLER SKAATS WHEELER, 1905-6.
SAMUEL SHELDON, 1906-7.
HENRY G. STOTT, 1907-8.
LOUIS A. FERGUSON, 1908-09.
LEWIS B. STILLWELL, 1909-10.
DUGALD C. JACKSON, 1910-11.
GANO DUNN, 1911-12.
RALPH D. MERSHON, 1912-13.
C. O. MAILLOUX, 1913-14.

*Deceased.

HONORARY SECRETARY.

RALPH W. POPE,
33 West 39th Street New York.

GENERAL COUNSEL.

PARKER and AARON,
52 Broadway, New York.

STANDING COMMITTEES

Revised to Sept. 1, 1914

EXECUTIVE COMMITTEE.

P. M. Lincoln, Chairman,
W. E. and M. Company, East Pittsburgh, Pa.
C. A. Adams, G. A. Hamilton,
H. H. Barnes, Jr., William McClellan,
B. A. Behrend, N. W. Storer.

FINANCE COMMITTEE

J. F. Stevens, Chairman,
1326 Chestnut St., Philadelphia, Pa.
H. H. Barnes, Jr. B. Gherardi.

LIBRARY COMMITTEE.

Samuel Sheldon, Chairman,
198½ Schermerhorn St., Brooklyn, N. Y.
B. Gherardi, Harold Pender,
F. L. Hutchinson, W. I. Slichter.

MEETINGS AND PAPERS COMMITTEE.

L. T. Robinson, Chairman,
General Electric Company, Schenectady, N. Y.
L. W. Chubb, H. H. Norris,
S. M. Kintner, C. P. Steinmetz, and the chairmen of all technical committees.

EDITING COMMITTEE.

H. H. Norris, Chairman,
239 West 39th St., New York.
M. G. Lloyd, W. S. Rugg,
A. S. McAllister, W. I. Slichter.

BOARD OF EXAMINERS.

Maurice Coster, Chairman,
165 Broadway, New York.
Philander Betts, A. S. McAllister,
Henry Floy, John B. Taylor.

SECTIONS COMMITTEE.

H. A. Horner, Chairman,
Hamilton Court, 39th and Chestnut Streets, Philadelphia, Pa.
Frederick Bedell, W. A. Hall,
H. W. Flashman, F. D. Nims,
Charles F. Scott, and the chairmen of all Institute Sections.

STANDARDS COMMITTEE.

A. E. Kennelly, Chairman,
Harvard University, Cambridge, Mass

C. A. Adams, Secretary,
Harvard University, Cambridge, Mass.

James Burke, W. H. Powell,
W. A. Del Mar, Charles Robbins,
H. W. Fisher, L. T. Robinson,
H. M. Hobart, E. B. Rosa,
P. Junkersfeld, C. E. Skinner,
G. L. Knight, J. M. Smith,
W. L. Merrill, H. G. Stott,
P. H. Thomas.

CODE COMMITTEE.

Farley Osgood, Chairman,
763 Broad Street, Newark, N. J.
J. C. Forsyth, George F. Sever,
H. B. Gear, H. O. Lacount,
H. N. Muller, C. E. Skinner,
A. M. Schoen, H. R. Sargent.

LAW COMMITTEE.

[Not yet appointed.]

SPECIAL COMMITTEES

Revised to Sept. 1, 1914.

POWER STATIONS.

[Not yet appointed.]

TRANSMISSION COMMITTEE.

P. H. Thomas, Chairman,
2 Rector St., New York.
E. J. Berg, V. D. Moody,
P. M. Downing, F. D. Nims,
A. R. Fairchild, F. W. Peek, Jr.,
F. A. Gaby, Harold Pender,
L. E. Imlay, K. C. Randall,
L. R. Lee, C. S. Ruffner,
G. H. Lukes, F. D. Sampson,
Ralph D. Mershon, P. W. Sothman,
W. E. Mitchell, C. E. Waddell,
J. E. Woodbridge.

PROTECTIVE APPARATUS.

[Not yet appointed.]

RAILWAY COMMITTEE.

D. C. Jackson, Chairman,
Massachusetts Institute of Technology, Boston, Mass.
A. H. Armstrong, E. B. Katte,
A. H. Babcock, Paul Lebenbaum,
E. J. Blair, W. S. Murray,
H. M. Brinckerhoff, Clarence Renshaw,
E. P. Burch, A. S. Richey,
H. M. Hobart, F. J. Sprague,
N. W. Storer.

ELECTRIC LIGHTING COMMITTEE.

Clayton H. Sharp, Chairman,
556 East 80th St., N. Y.
J. W. Cowles, H. W. Peck,
E. P. Hyde, S. G. Rhodes,
P. Junkersfeld, E. B. Rosa,
A. S. Loizeaux, G. H. Stickney,
T. S. Perkins, C. W. Stone.

INDUSTRIAL POWER COMMITTEE.

D. B. Rushmore, Chairman,
General Electric Company Schenectady, N. Y
A. C. Eastwood, J. P. Mallett,
Walter A. Hall, E. H. Martindale,
J. M. Hipple, W. L. Merrill,
G. H. Jones, J. A. Osborn,
C. D. Knight, A. G. Pierce,
J. C. Lincoln, H. A. Pratt.

TELEGRAPHY AND TELEPHONY COMMITTEE.

C. E. Scribner, Chairman,
463 West Street, New York.
C. L. Fortescue, William Maver, Jr.
H. M. Friendly, K. B. Miller,
A. H. Griswold, H. Mouradian,
F. B. Jewett, W. O. Pennell.
S. M. Kinter, Jr., J. B. Taylor,
J. L. Wayne.

COMMITTEE ON USE OF ELECTRICITY IN MINES.

Wilfred Sykes, Chairman,
Box 242, East Liberty, Pa.
P. E. Alexander, M. H. Gerry, Jr.
C. W. Beers, Charles Legrand,
W. W. Briggs, K. A. Pauly,
Graham Bright, G. B. Rosenblatt,
B. T. Viall.

COMMITTEE ON USE OF ELECTRICITY IN MARINE WORK

C. S. McDowell, Chairman.
Navy Yard, New York.
Maxwell W. Day, H. A. Horner,
W. L. R. Emmet, O. P. Loomis,
F. C. Hanker, D. M. Mahood,
H. L. Hibbard, Elmer A. Sperry,
Guy Hill, G. A. Pierce, Jr.,
F. W. Wood.

IRON AND STEEL INDUSTRY.

[Not yet appointed.]

ELECTROCHEMICAL COMMITTEE.

A. F. Ganz, Chairman.
Stevens Institute, Hoboken, N. J.
C. G. Schluederberg, C. F. Burgess,
W. R. Whitney, Lawrence Addicks,
Carl Hering, E. F. Price,
L. L. Summers.

ELECTROPHYSICS COMMITTEE.

J B. Whitehead, Chairman,
Johns Hopkins University, Baltimore, Md
Frederick Bedell, E. L. Nichols,
H. L. Blackwell, E. B. Rosa,
L. W. Chubb, H. J. Ryan,
W. S. Franklin, H. Clyde Snook.

RECORDS AND APPRAISALS OF PROPERTIES.

[Not yet appointed.]

EDUCATIONAL COMMITTEE.

V. Karapetoff, Chairman.
Cornell University, Ithaca, N. Y.
E. J. Berg, A. S. Langsdorf,
F. L. Bishop, C. E. Magnusson,
C. R. Dooley, Charles F. Scott,
G. A. Hoadley, P. B. Woodworth.

PUBLIC POLICY COMMITTEE.

Calvert Townley, Chairman,
165 Broadway, New York.
H. W. Buck, H. A. Lardner,
Fredk. Darlington, William McClellan,
Gano Dunn, E. W. Rice, Jr.,
J. H. Finney, L. B. Stillwell,
H. G. Stott.

PATENT COMMITTEE.

Ralph D. Mershon, Chairman,
80 Maiden Lane, New York.
Bion J. Arnold, O. S. Schairer,
C. S. Bradley, C. E. Scribner,
Val. A. Fynn, F. J. Sprague,
John F. Kelly, C. A. Terry,
H. Ward Leonard, E. S. Northrup.

MEMBERSHIP COMMITTEE.

H. D. James, Chairman,
W. E. and M. Company, East Pittsburgh, Pa.
Markham Cheever, A. G. Jones,
E. L. Doty, S. C. Lindsay,
Walter A. Hall, Herbert S. Sands,
Max Hebgen, M. S. Sloan,
H. A. Horner, W. S. Turner,
P. B. Woodworth.

HISTORICAL MUSEUM COMMITTEE.

T. C. Martin, Chairman,
29 West 39th Street, New York.
John J. Carty, E. W. Rice, Jr.,
Charles L. Clarke, Charles F. Scott,
Louis Duncan, Frank J. Sprague.

U. S. NATIONAL COMMITTEE OF THE INTERNATIONAL ELECTROTECHNICAL COMMISSION

C. O. Mailloux, President,
90 West Street, New York
F. B. Crocker, Vice-Pres., A. E. Kennelly, Sec.,
Harvard University, Cambridge, Mass.
C. A. Adams, E. B. Rosa,
B. A. Behrend, C. F. Scott,
James Burke, C. H. Sharp,
Louis Bell, C. E. Skinner,
J. J. Carty, Samuel Sheldon,
Gano Dunn, Charles P. Steinmetz,
H. M. Hobart, H. G. Stott,
J. W. Lieb, Elihu Thomson.
Philip Torchio.

INTERNATIONAL ELECTRICAL CONGRESS, SAN FRANCISCO, 1915. EXECUTIVE COMMITTEE OF COMMITTEE ON ORGANIZATION.

Charles P. Steinmetz, Honorary President of Congress,
E. B. Rosa, Honorary Secretary of Congress,
H. G. Stott, Chairman,
600 West 59th Street, New York,
John W. Lieb, Jr., Vice-Chairman,
C. O. Mailloux, Chairman, Sub-Committee on International Relations,
A. E. Kennelly, Chairman, Sub-Committee on Program,
Henry A. Lardner, Chairman, Sub-Committee on Pacific Coast Relations,
H. H. Barnes, Jr., Chairman, Sub-Committee on Transportation,
George F. Sever, Chairman, Sub-Committee on Entertainment,
Preston S. Millar, Secretary-Treasurer and Chairman, Sub-Committee on Publicity. 556 East 80th Street, New York,
F. L. Hutchinson, Secretary, A. I. E. E. [*Ex Officio*].

COMMITTEE ON RELATIONS OF CONSULTING ENGINEERS.

L. B. Stillwell, Chairman,
100 Broadway, New York.
H. W. Buck, F. R. Ford,
Gano Dunn, F. N. Waterman.

COMMITTEE ON CODE OF PRINCIPLES OF PROFESSIONAL CONDUCT.

George F. Sever, Chairman,
13 Park Row, New York.
H. W. Buck, John F. Kelly,
Gano Dunn, Schuyler Skaats Wheeler.

EDISON MEDAL COMMITTEE.

Appointed by President for terms of five years.

Term expires July 31, 1919.
Charles F. Brush, William Stanley,
N. W. Storer.

Term expires July 31, 1918.
H. W. Buck, J. Franklin Stevens,
F. A. Scheffler.

Term expires July 31, 1917.
A. E. Kennelly, H. Ward Leonard,
Robert T. Lozier.

Term expires July 31, 1916
Frank J. Sprague
Schuyler Skaats Wheeler, Chairman,
Ampere, N. J.
W. D. Weaver.

Term expires July 31, 1915.
Elihu Thomson, J. W. Lieb, Jr.,
E. L. Nichols.

Elected by the board of Directors from its own membership for terms of two years.

Term expires July 31, 1915.
H. H. Barnes, Jr., William McClellan,
A. S. McAllister.

Term expires July 31, 1916.
C. E. Scribner, C. O. Mailloux,
L. T. Robinson.

Ex-Officio.

P. M. Lincoln, President.
F. L. Hutchinson, Secretary.
George A. Hamilton, Treasurer.

INSTITUTE REPRESENTATIVES

ON BOARD OF AWARD, JOHN FRITZ MEDAL

Dugald C. Jackson, Ralph D. Mershon,
Gano Dunn, C. O. Mailloux.

ON BOARD OF TRUSTEES, UNITED ENGINEERING SOCIETY.

Gano Dunn, Charles E. Scribner.
H. H. Barnes, Jr.

ON LIBRARY BOARD OF UNITED ENGINEERING SOCIETY.

Samuel Sheldon, Harold Pender,
B. Gherardi, W. I. Slichter,
F. L. Hutchinson.

ON ELECTRICAL COMMITTEE OF NATIONAL FIRE PROTECTION ASSOCIATION.

The chairman of the Institute's Code Committee,
Farley Osgood.

ON ADVISORY BOARD OF AMERICAN YEAR-BOOK.

Edward Caldwell.

ON ADVISORY BOARD, NATIONAL CONSERVATION CONGRESS.

Calvert Townley.

ON COUNCIL OF AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

W. S. Franklin. G. W. Pierce.

ON CONFERENCE COMMITTEE OF NATIONAL ENGINEERING SOCIETIES.

Calvert Townley, William McClellan.

ON JOINT COMMITTEE ON ENGINEERING EDUCATION.

Charles F. Scott, Samuel Sheldon.

ON AMERICAN ELECTRIC RAILWAY ASSOCIATION'S COMMITTEE ON JOINT USE OF POLES.

Farley Osgood, F. B. H. Paine,
Percy H. Thomas.

ON NATIONAL JOINT COMMITTEE ON OVERHEAD LINE CONSTRUCTION.

Farley Osgood, F. B. H. Paine,
Percy H. Thomas.

ON NATIONAL COMMITTEE ON ELECTROLYSIS.

Bion J. Arnold, F. N. Waterman,
Paul Winsor.

ON BOARD OF MANAGERS, PANAMA-PACIFIC INTERNATIONAL ENGINEERING CONGRESS, 1915.

A. M. Hunt. J. G. DeRemer.
And the President and Secretary of the Institute.

LOCAL HONORARY SECRETARIES.

Guido Semenza. N. 10, Via S. Radegonda, Milan, Italy.
Robert Julian Scott. Christ Church, New Zealand.
L. A. Herdt, McGill Univ., Montreal Que.
Henry Graftio, St. Petersburg. Russia.
Clare F. Beames, Bangalore, Mysore Province. India,
Richard O. Heinrich, Genest-str. 5 Schoeneberg, Berlin, Germany.
A. S. Garfield, 67 Avenue de Malakoff, Paris, France.

LIST OF SECTIONS

Atlanta, chairman, A. M. Schoen; secretary, H. M. Keys, Southern Bell Tel. & Tel. Co., Atlanta, Ga.

Baltimore, chairman, J. B. Whitehead; secretary, L. M. Potts, Industrial Building, Baltimore, Md.

Boston, chairman, George W. Palmer, Jr.; secretary, Harry F. Thomson, Massachusetts Institute of Technology, Boston, Mass.

Chicago, chairman, E. W. Allen; secretary, W. J. Norton, 112 W. Adams Street, Chicago, Ill.

Cleveland, chairman, A. C. Eastwood; secretary, R. E. Scoval, 1663 East 86th Street, Cleveland, Ohio.

Detroit-Ann Arbor, chairman, H. H. Norton; secretary, Ray K. Holland, Cornwell Building, Ann Arbor, Mich.

Fort Wayne, chairman, L. D. Nordstrom; secretary, J. J. A. Snook, 1117 Fairfield Avenue, Ft. Wayne, Ind.

Indianapolis-Lafayette, chairman, O. S. More; secretary, G. B. Schley, 908 Hume-Mansur Building, Indianapolis, Ind.

Ithaca, chairman, E. L. Nichols; secretary, George S. Macomber, Cornell University, Ithaca, N.Y

Los Angeles, chairman, C. G. Pyle; secretary, Edward Woodbury, Pacific Lt. & Pr. Company, Los Angeles, Cal.

Lynn, chairman, W. H. Pratt; secretary, F. S. Hall, General Electric Co., Lynn, Mass.

Madison, chairman, J. W. Shuster; secretary, F. A. Kartak, Univ. of Wisconsin, Madison, Wis.

Mexico,

Milwaukee, chairman, L. L. Tatum; secretary, W. J. Richards, National Brake and Electric Co. Milwaukee, Wis.

Minnesota, chairman, Leo H. Cooper; secretary, Emil Anderson, 1236 Plymouth Bldg., Minneapolis, Minn.

Panama, chairman, Hartley Rowe; secretary, Clayton J. Embree, Culebra, C.Z.

Philadelphia, chairman, H. F. Sanville; secretary, W. F. James, 1115 North American Bldg., Philadelphia, Pa.

Pittsburgh, chairman, J. W. Welsh; secretary, Charles R. Riker, Electric Journal, Pittsburgh, Pa.

Pittsfield, chairman, W. W. Lewis; secretary, M. E. Tressler, General Electric Company, Pittsfield, Mass.

Portland, Ore., chairman, R. F. Monges; secretary, Paul Lebenbaum, 45 Union Dept., Portland, Ore.

St. Louis, chairman, F. J. Bullivant; secretary, A. McR. Harrelson, Emerson Electric Mfg, Co. St. Louis, Mo.

San Francisco, chairman, C. J. Wilson; secretary, A. G. Jones, 819 Rialto Building, San Francisco, Cal.

Schenectady, chairman, George H. Hill; secretary, John R. Hewett, Gen. Elec. Co., Schenectady, N. Y.

Seattle, chairman, S. C. Lindsay; secretary, E. A. Loew, University of Washington, Seattle, Wash.

Spokane, chairman, J. W. Hungate; secretary, L. N. Rice, Parsons Hotel, Spokane, Wash.

Toledo, chairman, George E. Kirk; secretary, Max Neuber, Cohen, Freidlander & Martin, Toledo, O.

Toronto, chairman, D. H. McDougall, secretary, H. T. Case, Continental Life Bldg., Toronto, Ont.

Urbana, chairman, I. W. Fisk; secretary, P. S. Biegler, University of Illinois, Urbana, Ill.

Vancouver, chairman, E. M. Breed; secretary, L. G. Robinson, 1003 Holden Building, Vancouver, B. C.

Washington, D.C., chairman, C. B. Mirick; secretary, C. A. Peterson, Treasury Department, Washington, D. C.

LIST OF BRANCHES

Agricultural and Mechanical College of Texas, chairman, D. B. Pickens; secretary, E. C. Rack, A & M. College, College Station, Tex.

Arkansas, Univ. of., chairman, S. S. McGill; secretary, M. B. Roys, Univ. of Arkansas, Fayetteville Ark.

Armour Institute, chairman, E. L. Nelson; secretary, T. C. Bolton, Armour Inst. Tech., Chicago, Ill.

Bucknell University, chairman, F. O. Schnure; secretary, J. M. Hillman, Bucknell University, Lewisburg, Pa.

California, Univ. of., chairman, L. R. Chilcote; secretary, E. S. Middaugh, University of California, Berkeley, Cal.

Cincinnati, Univ. of., chairman, M. L. Harned; secretary, A. C. Perry, University of Cincinnati, Cincinnati, O.

Clemson Agricultural College, chairman, F. J. Jervey; secretary, F. H. McDonald, Clemson College, S. C.

Colorado State Agricultural College, chairman, L. M. Klinefelter; secretary, R. K. Havighorst, Colorado State Agricultural College, Fort Collins, Colo.

Colorado, Univ. of., chairman, Philip S. Borden; secretary, Charles S. Miller, University of Colorado, Boulder, Colo.

Georgia School of Technology,

Highland Park College, chairman, Clyde Prussman; secretary, Ralph R. Chatterton, Highland Park College, Des Moines, Iowa.

Idaho, University of.,

Iowa State College, chairman, Earle G. Nichols; secretary, F. A. Robbins, Iowa State College, Ames, Iowa.

Iowa, Univ. of., chairman, J. H. Scanlon; secretary, A. H. Ford, University of Iowa, Iowa City, Ia.

Kansas State Agr. Col., chairman, L. O'Brien; secretary, W. C. Lane, Kansas State Agric. Col., Manhattan, Kan.

Kansas, Univ. of., chairman, H. C. Hansen; secretary, L. M. Bocker, Univ. of Kansas, Lawrence, Kansas.

Kentucky State Univ. of., chairman, H. B. Hedges; secretary, H. Tyler Watts, 315 East Maxwell Street, Lexington, Ky.

Lafayette College, chairman, R. McManigal; secretary, W. J. English, Jr., Lafayette College, Easton, Pa.

Lehigh University, chairman, N. F. Matheson; secretary, F. C. Brockman, Lehigh University, S. Bethlehem, Pa.

Lewis Institute, chairman, A. H. Fensholt; secretary, Fred A. Rogers, Lewis Institute, Chicago, Ill.

Maine, Univ. of., chairman, C. M. Kelly; secretary, E. L. Getchell, University of Maine, Orono, Maine.

Michigan, Univ. of., chairman, H. A. Enos; secretary, H. W. Stubbs, University of Michigan, Ann Arbor, Mich.

Missouri, Univ. of., chairman, E. W. Kellogg; secretary, K. Atkinson, University of Missouri, Columbia, Mo.

Montana State Col., chairman, John M. Fiske; secretary, J. A. Thaler, Montana State College, Bozeman, Mont.

Nebraska, Univ. of., chairman, Olin J. Ferguson; secretary, V. L. Hollister, Station A, Lincoln, Nebraska.

New Hampshire Col.,

North Carolina Col. of Agr. and Mech. Arts, chairman, Wm. H. Browne, Jr., secretary, James Fontaine, West Raleigh, N. C.

Ohio Northern Univ., chairman, A. B. Curtis; secretary, W. F. Schott, Ohio Northern University, Ada, Ohio.

Ohio State Univ., chairman, Leslie J. Harter; secretary, Robert C. Schott, Ohio State Univ., Columbus, Ohio.

Oklahoma Agricultural and Mech. Col., chairman, A. P. Little; secretary, Quentin Graham, 118 Husband St., Stillwater, Okla.

Oklahoma, Univ. of., chairman, R. D. Evans; secretary, L. J. Hibbard, Univ. of Oklahoma, Norman, Okla.

Oregon Agr. Col., chairman, A. O. Manigold; secretary, I. L. Olmstead, Oregon Agric. Col., Corvallis, Ore.

Penn State College, chairman, A. D. Shultz; secretary, A. T. McNeile, State College, Pa.

Pittsburgh, University of., chairman, B. E. O'Hagan; secretary, George Hickman, University of Pittsburgh, Pittsburgh, Pa.

Purdue Univ., chairman, L. W. Spray; secretary, R. E. Tafel, Purdue University, Lafayette, Ind.

Rensselaer Poly. Inst., chairman, W. J. Williams; secretary, H. F. Wilson, Rensselaer Poly. Institute, Troy, N. Y.

Rose Polytechnic Inst., chairman, Charles F. Harris; secretary, Claude A. Lyon, 1331 Liberty Avenue, Terre Haute, Ind.

Rhode Island State Col., chairman, W. C. Miller; secretary, P. M. Randall, Jr., Rhode Island State College, Kingston, R. I.

Stanford Univ., chairman, G. L. Beaver; secretary, H. J. Scholz, Stanford University, Cal.

Syracuse Univ., chairman, W. P. Graham; secretary, R. A. Porter, Syracuse University, Syracuse, N. Y.

Texas, Univ. of., chairman, Joseph W. Ramsey; secretary, J. A. Correll, University of Texas, Austin, Tex.

Throop College of Technology, chairman, W. L. Newton; secretary, A. W. Wells, Throop Poly. Institute, Pasadena, Cal.

Virginia, Univ. of., chairman, Walter S. Rodman; secretary, H. Anderson, Jr., 1022 West Main St., Charlottesville, Va.

Wash., State Col. of., chairman, M. K. Akers; secretary, H. V. Carpenter, State Coll. of Wash., Pullman, Wash.

Washington Univ., chairman, R. D. Duncan, Jr.; secretary, C. C. Hardy, Washington University, St. Louis, Mo.

Washington, Univ. of., chairman, H. W. McRobbie; secretary, B. B. Bessesen, Univ. of Washington, Seattle, Wash.

Worcester Poly. Inst., chairman, Frank Aiken; secretary, A. B. R. Prouty, Worcester Poly. Inst., Worcester, Mass.

Yale University, chairman, F. M. Doolittle; secretary, W. L. Kenly, New Haven, Conn.

SECTION II

PROCEEDINGS

of the

American Institute

of

Electrical Engineers

Papers, Discussions and Reports

CONTENTS OF SECTION II

PROCEEDINGS

OF THE

American Institute

OF

Electrical Engineers.

Published monthly by the A. I. E. E., at 33 W. 39th St., New York, under the supervision of

THE EDITING COMMITTEE

GEORGE R. METCALFE, Editor

Subscription. $10.00 per year for all countries to which the bulk rate of postage applies.
All other countries $12.00 per year.
Single copy $1.00.
Subscriptions must begin with January issue.

Changes of advertising copy should reach this office by the 15th of the month, for the issue of the following month

Vol. XXXIII **October, 1914** No. 10

Institute Meeting in New York, October 9, 1914

The 299th meeting of the American Institute of Electrical Engineers will be held in the auditorium of the Engineering Societies Building, 33 West 39th Street, New York, on Friday, October 9th, at 8:15 p.m. The general subject of the meeting will be "Protective Reactances," and two papers will be presented, as follows: *Protective Reactances for Feeder Circuits of Large City Power Systems*, by Messrs. James Lyman, Leslie L. Perry, and A. M. Rossman, and *Use of Reactance with Synchronous Converters*, by J. L. McK. Yardley.

The former paper outlines the use and limitations of protective reactance coils in feeder circuits. When no feeder reactances are used, doubling up the station capacity increases the number and severity of short circuits. The insertion of feeder reactances cuts down the severity of a short circuit and practically renders the effect local so that beyond a certain point additional generator capacity does not appreciably increase the severity of short circuits.

The second paper considers the use of reactance with synchronous converters as an insurance of continuity of service and a protection to the apparatus. Three conditions of service are considered with regard to use of protective reactances, as follows:—(1) where it is important to keep voltage on the lines at all times, (2) where heavy overloads are frequent, but where, to protect apparatus and maintain service, voltage may be allowed to drop during overloads, (3) where high momentary overloads are frequent, without appreciable voltage drop, but where brief interruptions are not objectionable.

Advance copies of these papers will be available a few days before the meeting and may be obtained on application to the Secretary.

Institute Meeting in Philadelphia, October 12, 1914

The 300th meeting of the American Institute of Electrical Engineers will be held at Philadelphia, Pa., October 12, 1914, under the auspices of the Committee on the Use of Electricity in Marine Work and the Philadelphia Section of the A.I.E.E. The headquarters of the Institute during the meeting will be at the Engineering Building, University of Pennsylvania, 33rd and Locust Streets. The first session will be opened at 2 o'clock and two papers will be presented, as follows: *Submarine Signaling*, by R. F. Blake; *The Electrical Equipment of the Argentine Battleship Moreno*, by H. A. Hornor.

At 6 p. m. dinner will be served at The Normandie, 36th and Chestnut Streets. $1.00 per cover.

The evening session will be opened at 8:15 p.m. and a paper will be presented, entitled *Electrical Features of the U. S. Reclamation Service*, by F. H. Newell.

The three papers for this meeting are printed in Section II of this issue of the PROCEEDINGS.

Membership Campaign

Have you thought what the Institute means to you? Have you told a fellow engineer about it this fall? Don't wait until after Christmas, start now. In case your memory is rusty after the vacation period, I have summarized a few of the reasons for joining the A.I.E.E. You can easily add more; then repeat them to others. Make it a point to say a good word for the Institute whenever you have a chance.

Reasons for joining the A. I. E. E.

1. One should be a member of the National Society that represents his profession. The first estimate of an electrical engineer is often made by referring to our membership list. The high character of men whose names are found there gives real prestige to the engineer who wears the badge.

2. Every live electrical engineer should have the technical information made available through the PROCEEDINGS and TRANSACTIONS of the A. I. E. E. It is true that every library of repute can furnish this information, but how many books of value are there in the same library that an engineer never looks at. Every engineer takes pride in the possession of the technical books that form the foundation of his knowledge. The book or magazine that lies on his library table is the one he reads. When he has an hour of leisure in the evening and is comfortably settled in his own room, it is very unlikely that he will go out to the library. At such times his copy of the PROCEEDINGS is of real value to him.

3. The up-to-date engineer must meet with other engineers to discuss the live problems of his profession. The Institute holds meetings in 100 different places, most of them monthly from October to May. If one is so unfortunate as to live where there are no organized Institute meetings, he should endeavor to organize, for he cannot afford to be without the stimulus of personal contact with other engineers. There is nothing like a discussion to sharpen a man's perceptions and lift him out of a rut. If there are not enough engineers in the neighborhood to form a Section the PROCEEDINGS will be doubly valuable.

4. Do something for your own profession. The Institute is doing a splendid work for the electrical engineer and every man in that profession should do his part. For a better appreciation of the work of the Institute and the advantages of membership, one should read the masterly addresses of President C.F. Scott before the A.I.E.E. in September, 1902, and President S. S. Wheeler on "Engineering Honor" in May, 1906.*

The list of committees in this issue of the PROCEEDINGS gives some idea of the Institute work. As an example of this work refer to the recent revision of the "Standardization Rules," which is the result of continued effort by the Standards Committee, with the assistance of many other prominent members of the Institute. Their research work required long and careful investigations, and these investigations are recorded in many papers presented before the Institute during the last two years.

If it were not for the A. I. E. E., who would carry on the work of our Central Office in New York? Who would represent the American Electrical Engineer in his relations with other organizations or foreign engineering societies?

There are many very good reasons for joining the A. I. E. E., but the four given above show the personal advantage to the engineer himself and his duty to the public and to other engineers.

Every member of the Institute should be proud of his society and glad to present its advantages to other engineers. Don't talk membership at first, talk of the Institute work and the advantages you derive from membership. If you interest your friend he

*Note especially the address on *The Evolution of the Institute and of Its Members*, by **President** C. O. Mailloux, in this issue of the PROCEEDINGS, beginning on page 1427, Section II.

will bring up the subject of joining and be glad to apply for membership.

If the membership as a whole takes part in this effort to increase the numbers and influence of the Institute, the result will not only be more members, but every one who works for the Institute will take a deeper interest in its work and we will have a better organization.

Let every member try, for his own benefit, to get a new member and then see how much more the A. I. E. E. means to him. Work of this kind is both inspiring and contagious.

H. D. JAMES,
Chairman, Membership Committee.

The Sixth Annual Pacific Coast Meeting

The sixth annual Pacific Coast Convention of the A. I. E. E. was held in Spokane, Washington, September 9th, 10th, and 11th, 1914, the two following days being devoted to trips to power plants.

This was held in conjunction with the annual convention of the Northwest Electric Light and Power Association, which is affiliated with the N. E. L. A. The convention was pronounced a success in every way, and in addition to the serious side of it there were entertainment features which were much enjoyed by the members and guests.

The headquarters of the two associations was the new Hotel Davenport, a $2,000,000 structure which had been open to the public one week only, when the convention met. The sessions of the N. E. L. & P. A. were held in the *Elizabethan* banquet hall and those of the Institute in the beautiful *Marie Antoinette* ballroom.

The total registration for the Institute reached 192 members and guests. This included 71 out-of-town members and guests, 78 local members, 33 ladies, both out-of-town and local. Mr. Paul M. Lincoln, president of the Institute, and Mr. Ralph W. Pope, honorary secretary, attended the convention. President Lincoln presided at most of the sessions and took a very active part in the discussions also. Following the custom of these conventions, he invited to the chair, during the reading and discussion of each paper, one of the chairmen of the Pacific Coast Sections. Secretary Pope also took an active part in the discussions and the post-prandial oratory.

The joint opening session was called to order at 10:00 a.m. Wednesday, September 9th. In the absence of Mr. D. L. Huntington of Spokane, chairman of the Convention Committee, the chair was occupied by Mr. H. L. Bleecker of Spokane, president of the N. E. L. & P. A. The chairman introduced the Hon. W. J. Hindley, mayor of Spokane, who gave a very stirring address of welcome. The mayor's kindly words were most fittingly responded to by Mr. N. W. Brockett of Seattle. The meeting then resolved into separate technical sessions.

The first Institute session was called to order by Mr. J. B. Fisken, vice-chairman of the Convention Committee. In his opening remarks, Mr. Fisken stated that President Lincoln had for a long time been chairman of the Sections Committee and that it was due in large measure to his efforts that the Sections had reached their present state of development. The Pacific Coast Convention was the natural result of the organization of Sections in the Pacific Coast cities. Mr. Lincoln was then called to the chair, when he was presented with a gavel by Mr. J. W. Hungate, chairman of the Spokane Section. Mr. Hungate stated that this gavel, the gift of his Section, had considerable historical interest, the handle being made from a pole and the head from a crossarm, both of which had been in service in Spokane for twenty-five years. Mr. Lincoln replied to Mr. Fisken and Mr. Hungate, and then called for the first paper, "The Effect of Delta and Star Connections Upon Transformer Wave

Forms," by Mr. Leslie F. Curtis of the University of Washington, which brought out a very interesting discussion.

At 2:00 p.m. the same day, the two associations convened in joint session to hear a scholarly address on "Rates and Physical Valuation of Public Utilities," by Mr. W. W. Cotton, of the Multnomah Bar Association, of Portland, Oregon. There was no discussion. The next two papers given that afternoon were "Outdoor Substations," by Mr. J. C. Martin of the Pacific Power and Light Company, and "Electric Power Development on the Pacific Coast," by Mr. W. E. Herring, of the Puget Sound Traction, Light and Power Company. Both papers brought out long and interesting discussions, it being dinner time before the meeting adjourned.

Thursday morning the members listened to a paper by Mr. Edward Woodbury on "Some Operating Conditions of the 150,000-Volt Transmission System of the Big Creek Development of the Pacific Light and Power Corporation." After the discussion of this paper, Mr. F. D. Nims of the Western Canada Power Company read his paper, "A Distribution System for Power Purposes."

At the Thursday afternoon session, the members listened to a paper by Mr. E. F. Whitney, entitled "Electricity in the Lumber Industry," and later to another paper by Mr. J. B. Cox of the General Electric Company, on "The Butte, Anaconda and Pacific Railway." Mr. Cox gave some of the most complete statistics ever given of electric railway maintenance costs and operating features.

Friday morning a paper was read by Mr. G. B. Rosenblatt of the Westinghouse Electric and Manufacturing Company, entitled the "Application of Electric Motors to Gold Dredges." After the discussion, Mr. M. T. Crawford gave his paper, "Economy in the Operation of 55,000-Volt Insulators."

At the afternoon meeting, the "Report of the Joint Committee on Inductive Interference" was read by Mr. L. B. Ferris of the Pacific Telephone & Telegraph Company, San Francisco. This gave the results of the exhaustive work done by this Joint Committee in California and proved a most interesting paper. After the discussion, President Lincoln declared the technical sessions of the convention closed.

Entertainment

The entertainment provided by the Spokane Section and the local companies was very complete. The visiting ladies were well taken care of by the local ladies on the reception committee during the time that the associations were in session.

Wednesday the visiting ladies were entertained at afternoon tea at the Hotel Davenport, and in the evening were given a theater party. While the ladies were enjoying vaudeville that night, the men had a little party of their own in the form of a "Dutch lunch" in the Hall of the Doges at Davenport's.

The next afternoon the ladies enjoyed an automobile trip around the city, and later, afternoon tea at the Country Club, nine miles from Spokane, returning in time for dinner. That evening all the members and ladies listened to an illustrated talk by Mr. A. H. Halloran of San Francisco on "The Electrical Features of the Panama-Pacific Exposition." This was followed by motion pictures showing the "Development of the Telephone." This was presented by the Pacific Telephone and Telegraph Company. Those who wished then adjourned to Davenport's restaurant for music and refreshments, the center section of the cafe being reserved for convention members.

Friday morning the ladies took an automobile trip to Hayden Lake, 40 miles from Spokane, and enjoyed a chicken dinner at picturesque Bozanta Tavern. In the evening the members

of both associations attended the convention banquet, held in the Marie Antoinette ballroom. During the banquet, the members were entertained by orchestra and singing, thanks to the hotel management. The toastmaster of the evening was Mr. O. B. Coldwell, President-elect of the N. E. L. & P. A. Toasts were responded to by Mr. Pope, Mr. N. W. Brockett of Seattle, and President Lincoln. While the men were enjoying themselves in the banquet room, the ladies attended the Auditorium Theater, where Mr. S. E. Gates, chairman of the entertainment committee, had arranged for them to see the comedy "Kitty McKay."

Saturday morning, members and ladies, about 125 in all, took the all-day automobile trip to the Long Lake development of the Washington Water Power Company, about thirty-two miles down the river from Spokane. When completed this will be one of the largest hydraulic plants in the West. The power company was host to the visitors at a camp dinner. The Little Falls plant of the same company was also visited, six miles farther down the river. The Nine Mile plant of the Spokane and Inland Empire Railroad Company was inspected on the return trip.

On Sunday the members and ladies were guests of the Spokane and Inland Empire Railroad Company, on a ride over the system, about sixty being present. The first part of the trip was over the single-phase road to Waverly, where the party made an inspection of the single-phase substation. On the return to Spokane, a few minutes were spent visiting the frequency-changing station of the Inland Empire system. Then the journey was continued to Hayden Lake, for a chicken dinner at Bozanta Tavern. Hayden Lake is in northern Idaho, and is considered one of the most beautiful mountain lakes in the country. On the return trip a stop was made at Post Falls to look over the Post Falls plant of the Washington Water Power Company.

Electric Vehicle Association of America

The Electric Vehicle Association will hold its fifth annual convention, Monday, Tuesday and Wednesday, October 19, 20 and 21, at the Hotel Bellevue-Stratford, Philadelphia.

The unusually complete program of papers will contain a great quantity of actual operating data of inestimable value, which, in itself, justifies a large attendance. Besides, there will be many valuable committee reports, and practical reports of profitable sales campaigns, while the entertainment features will be added attractions.

Additional information, including program, hotel reservations, et cetera, can be obtained upon application to the General Office of the Association, 29 West 39th Street, New York.

The members of the American Institute of Electrical Engineers have been cordially invited to attend this convention.

Applications for Election

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before October 31, 1914.

Anthonisen, R. P., Chicago, Ill.
Ashley, A. H., Detroit, Mich.
Ayya, D. V., Hyderabad, India.
Betcher, B. L., Rock Springs, Wyo.
Birdsall, A. G., S. Bethlehem, Pa.
Bowers, F. E., Detroit, Mich.
Chapman, H. B., Detroit, Mich.
Clover, G. R., Detroit, Mich.
Engleheart, P., Zamora, Mexico.
Estey, F. C., Peabody, Mass.
Georgi, J. A., Detroit, Mich.

Glaspey, R. M., Harrisburg, Pa.
Green, R. E., Chicago, Ill.
Gunn, A., Wenatchee, Wash.
Homrighaus, A. H., Detroit, Mich.
Hook, E. B., Jr., Atlanta, Ga.
Hopkins, A. H., Greenwood, B. C.
Hoppin, G. H., Spokane, Wash.
Huang, S. V., Schenectady, N. Y.
Hughes, E. C., Providence, R. I.
Hurst, E. J., Atlanta, Ga.
Klapper, C., St. Paul, Minn.
Lines, N. R., Malmo, Sweden.
Long, K. T., Tientsin, China.
Mahar, E. W., St. Paul, Minn.
Mample, A. Z., Minneapolis, Minn.
Mark, W. J., St. Paul, Minn.
Marshall, J. D., St. Paul, Minn.
North, C., Revelstoke, B. C.
Peck, D. L., Detroit, Mich.
Pellens, F. T., Birmingham, Ala.
Perkins, H. S., Detroit, Mich.
Pirkl, A. J., St. Paul, Minn.
Player, G. P., Jefferson City, Mo.
Rickerby, W. J., New York, N. Y.
Seguin, L. Z., Detroit, Mich.
Simpson, R., Chicago, Ill.
Steward, C. P., Milwaukee, Wis.
Tarran, L., San Francisco, Cal.
Vidro, E. F., Detroit, Mich.
Wilsher, E. H., Detroit, Mich.
Wise, C. E., Detroit, Mich.
Woo, T. Y., Schenectady, N. Y.

Personal

MR. GEORGE B. TRIPP recently resigned his position as general manager of the Harrisburg Light and Power Company, Harrisburg, Pa., to become an operating executive of the United Gas and Electric Corporation, 61 Broadway, New York.

MR. FRANK F. FOWLE, consulting engineer, has closed his New York office on account of the extensive nature of his duties as one of the receivers of the Central Union Telephone Company, Chicago, and has removed his headquarters to 212 West Washington Street, Chicago.

MR. JOHN Z. KELLY has resigned his position with the New York office of the Westinghouse Electric and Manufacturing Company, to become the New York representative of the Reliance Electrical and Engineering Company, of Cleveland, Ohio, with office at 90 West Street, New York.

MR. F. I. WOLTZ, who has been in the employ of the Great Shoshone and Twin Falls Water Power Company, Twin Falls, Idaho, during the past four years, has tendered his resignation as commercial engineer, to accept a similar position with the Union Gas and Electric Company, of Cincinnati, Ohio.

MR. CLARENCE D. CLARK, on account of the reorganization of districts and abolishing of divisions by the Pacific Gas and Electric Company, has had his duties, formerly those of superintendent of the North Tower Power Division, extended to include all of the company's activities, both gas and electric transmission and distribution, in the cities and suburbs of Napa, Cordelia and Vallejo, California, with the title of manager of Napa District.

MR. WILLARD DOUD, formerly engineer of shop improvements for the Chicago, Burlington and Quincy and the Illinois Central Railroads, and recently engaged in the design and equipment of new shops at Clearing, Ill., for the Belt Railway of Chicago, has completed this work and opened offices at 538 South Dearborn Street, Chicago, for the handling of all matters pertaining to the design, construction, equipment and operation of railroad and industrial shops, factories and power plants.

MR. W. N. DICKINSON, who has been for some years connected with the Otis Elevator Company and a leader in alternating-current elevator motor development, is now connected with the General Elevator Company, 29 Broadway, New York. Mr. Dickinson has

been in recent years manager of the foreign department of the Otis Elevator Company. Prior to that appointment he was temporarily in charge of their Chicago Works and Middle West construction, and later had charge of their engineering on the Pacific Coast.

Mr. Fred B. Corey, formerly for eleven years in the engineering department of the General Electric Company, who for the past three years has been engineer of inspection and tests for the Union Switch and Signal Company, has resigned that position and opened an office at 404 Arrott Building, Pittsburgh, Pa. He will conduct a consulting engineering business, making a specialty of inspection methods and organizations for manufacturing companies, and also giving attention to electric railway signaling and allied subjects.

Obituary

Henry Heim, operator for the Marconi Wireless Telegraph Company, was accidentally killed on August 18, 1914, in that company's new wireless station near Bolinas, California. He was a young electrical engineer of promising ability and fine character. He was to have been elected an Associate of the Institute, but before his election was formally completed the news of his untimely death was received.

Henry Harbinson Sinclair, a well-known hydroelectrical engineer, and pioneer in long-distance transmission, died at Pasadena, California, September 1, 1914.

During the twenty years he devoted to power development in California, there was solved with commercial success, in nearly every project which he so ably managed, some great problem in electrical or hydraulic engineering which others had hesitated to attempt.

Mr. Sinclair was born in Brooklyn, New York, December 22, 1858. He was educated in the public schools and academies of that city. When fifteen years of age he went to sea for three years, and in 1876 entered Cornell University. Later he was engaged in the shipping business for several years in New York, following which he studied law at Columbia University. During subsequent legal experience his health failed, and he went to Redlands, California, in 1887, where he finally recovered.

In 1892 Mr. Sinclair organized the Redlands Electric Light and Power Company, becoming president and general manager. Power was developed from the comparatively small stream in Mill Creek Canyon, near Redlands. Mr. Sinclair and his colleagues were convinced by Mr. A. W. Decker, consulting engineer for the Mt. Lowe Railway, then building, that they would find themselves hampered by obsolete apparatus unless they developed, beyond the experimental stage, a plant capable of transmitting to any reasonable distance a new form of electrical energy—the three-phase. A plant was finally constructed, which is still furnishing power. This plant was the scene of experiments in new problems, especially that of operating three-phase generators in parallel. Here were used successfully the first three-phase generators, three-phase synchronous motor and three-phase induction motor ever manufactured.

In 1896 Mr. Sinclair was one of the organizers of the Southern California Power Company, which undertook the development of power in Santa Ana Canyon, near Redlands, and its transmission to Los Angeles, a distance of eighty-three miles, at 33,000 volts. The voltage and distance proposed were twice as great as in any long-distance line then existing or contemplated. During construction, the company's property was purchased by the Edison Electric Company of Los Angeles, and the entire system (the largest hydroelectric project of its time) was made a success, under the management of Mr. Sinclair and

superintendence of Mr. O. H. Ensign, now chief electrical engineer of the United States Reclamation Service. During this period, under Mr. Sinclair's management, the Mill Creek plant, with 1960 ft. head, was built. This was for many years the highest head in the world.

From 1901 to 1907 Mr. Sinclair was vice-president and general manager of the Edison Electric Company of Los Angeles, during which time the Kern River plant was built. After the completion of this plant, Mr. Sinclair maintained a consulting engineering office in Los Angeles until 1909, when he went to San Francisco to assume management of the Great Western Power Company, which position he occupied for two years. During that time the company carried on construction of two monumental dams and developed an extensive power market.

After severing his connection with the Great Western Power Company, although because of failing health an immediate rest seemed imperative, his many interests in Southern and Lower California necessitated his maintaining an office in Los Angeles until 1914. During this time under his management the industrial city of Torrance was built, this being another example of his unusual executive ability.

Mr. Sinclair was elected an Associate of the American Institute of Electrical Engineers in 1909 and transferred to the grade of Member on November 14, 1913.

EDWARD J. HALL, vice-president of the American Telephone and Telegraph Company and chairman of the executive committee of the Western Union Telegraph Company, died September 17, 1914, at Watkins, N.Y., at the age of 61. Mr. Hall had been in ill-health for several months and had not been as active as formerly in the telegraph and telephone companies.

Edward J. Hall was born in Perth Amboy, N. J., March 31, 1853. He was graduated from Sheffield Scientific School of Yale University in 1873. In 1878, in the year following the organization of the parent company of the Bell telephone system, Mr. Hall obtained the right to operate in Buffalo, N. Y., under the patents owned by the Bell company, and organized a telephone company of which he became vice-president and general manager. When, on January 1, 1885, Theodore N. Vail, then general manager of the American Telephone Company, was developing the project to organize the American Telephone and Telegraph Company, he asked Mr. Hall to take charge of the development of the new system. On January 1, 1887, under Mr. Hall's direction, the telephone line from New York to Philadelphia was opened to the public. Mr. Hall in recent years had been greatly interested in the development of the night letter and day letter telegraph service.

Mr. Hall was elected an Associate of the A. I. E. E. on April 18, 1893.

Library Accessions

The following accessions have been made to the Library of the Institute since the last acknowledgment.

American Electrochemical Society. Transactions vol. XXV. South Bethelehem, 1914. (Gift of Society.)

Boston Wire Department. Annual Report, 1913-14. Boston, 1914. (Gift of Department.)

Der Elektrische Starkstrom im Berg und Hüttenwesen. By W. von Winkler. Stuttgart, 1905. (Purchase.)

Der Elektrizitätszähler. By R. Ziegenberg. Berlin, 1912. (Purchase.)

Erläuterungen zu den Vorschriften für die Errichtung und den Betrieb elektrischer Starkstromanlagen. Ed. 11. By C. L. Weber. Berlin, 1912. (Purchase.)

Galvanischen Metallniederschläge und deren Ausfuhrung. By Hubert Steinach and Georg Buchner. Ed. 3. Berlin, 1911. (Purchase.)

Konstruktion, Bau und Betrieb von Funkeninduktoren und deren Anwendung. II teil: Roentgenstrahlentechnik. By Ernst Ruhmer. Berlin, 1914. (Purchase.)

Konstruktionen und Schaltungen aus dem Gebiete der elektrischen Bahnen. By O. S. Bragstad. Berlin, 1907. (Purchase.)

New Hampshire. Public Service Commission. Reports and orders. June 10, 1914 to July 28, 1914. (Gift of Public Service Commission.)

New York City. Board of Water Supply. Annual Report 8th, 1913. New York, 1913. (Gift of Board of Water Supply.)

Projektierung und Bau elektrischer Maschinen und Schaltanlagen. By G. Sattler. Leipzig, 1908. (Purchase.)

Rays of Positive Electricity and their application to Chemical Analyses. By J. J. Thomson. London, 1913. (Purchase.)

Stromquellen und Akkumulatoren. By J. Kollert und E. Sieg. (Handbuch der Elektrotechnik, Bd III.) Leipzig, 1901. (Purchase.)

Telephone Cables. By J. C. Slippy. Pittsburgh, 1913. (Gift of author.) Price $2.50.

Covers specifications for cables; plans for cable layout; construction; inspection; testing; and chapters on cable records and cable costs. A pocket size book for the cable engineer. W.P.C.

Theorie, Berechnung und Untersuchung von Transformatoren. By K. A. Schreiber. Stuttgart, 1912. (Purchase.)

Die Theorie des Bleiaccumulators. By Fredrich Dolezalek. Hallea.S.1901. (Purchase.)

Wentworth Institute. Catalogue 1914-15. Boston, 1914. (Gift of Institute.)

Zeitschrift fur Vermessungswesen. Vols. 1-35, 1872-1906. Stuttgart, 1873-1906.

——Inhaltsverzeichnis. vols. 1-33, 1872-1904. Stuttgart, 1906. (Gift of C. O. Mailloux.)

Trade Catalogues

Electric Storage Battery Co. Philadelphia, Pa. "Exide" Battery (type Z) for motorcycle service. Aug. 1914.

Johns-Manville Co. New York, N. Y. J. M. Roofing salesman. Aug. 1914.

Meirowsky Bros. Jersey City, N. J. Mica and quality insulations for electrical machinery and apparatus.

Ohio Brass Co. Mansfield, O. O.-B. Bulletin. July 1914.

Western Electric Co. New York, N. Y. Modern methods in train dispatching.

——Magneto telephones and supplies. 40pp.

——Telephone Cords. 16pp.

——Western Electric Poles. 12pp.

Westinghouse Machine Co. East Pittsburgh, Pa.

——WM506. Turbo-Alternators. May 1914.

——WM511. Leblanc Surface Condenser. May 1914.

——WM512. Leblanc Jet Condenser. May 1914.

United Engineering Society

Ammonia and its Compounds, their manufacture and uses. By Camille Vincent, translated from the French By M. J. Salter. London, 1901. (Purchase.)

Art of Paper Making. Ed. 4. By Alexander Watt. London, 1911. (Purchase.)

Bibliographie der Deutschen Zeitschriften Literatur. Band XXXIII A. Leipzig, 1914. (Purchase.)

Bibliographie der fremdsprachigen Zeitschriftenliteratur. Band VIII, 1913. Leipzig, 1914. (Purchase.)

Calculus for Engineers. By John Perry. London, 1897. (Purchase.)

Carnegie Endowment for International Peace. Report of the International Commission to inquire into the causes and conduct of the Balkan Wars. (Publication no. 4.) Washington, 1914. (Gift of R. A. Franks.)

Formules Recettes, Procédés. By L. Francois. Paris, 1914. (Purchase.)

Gesamt-Zeitschriften Verzeichnis. 1914. Berlin, 1914. (Purchase.)

Liquid Air Oxygen, Nitrogen. By Georges Claude. Philadelphia, 1913. (Purchase.)

Prevention of Dampness in Buildings. By Adolf W. Keim. London, 1902. (Purchase.)

Psychology of Management. By L. M. Gilbreth. New York, Sturgis & Walton, 1914. (Gift of Publishers.) Price $2.00.

A publication in book form of the essays appearing originally in *Industrial Engineering*. A careful study of the underlying principles ofScientific Management. W. P. C.

Recent Cotton Mill Construction and Engineering. Ed. 3. By Joseph and Frank Nasmith. Manchester, 1909. (Purchase.)

Small Water Supplies. By F. Noel Taylor. London, 1911. (Purchase.)

Textile Industries. 8 vols. By Wm. S. Murphy. Lond., 1912. (Purchase.)

OFFICERS AND BOARD OF DIRECTORS, 1914-1915

PRESIDENT.

(Term expires July 31, 1915.)

PAUL M. LINCOLN.

JUNIOR PAST-PRESIDENTS.

(Term expires July 31, 1915.)
RALPH D. MERSHON.

(Term expires July 31, 1916.)
C. O. MAILLOUX.

VICE-PRESIDENTS.

(Term expires July 31, 1915.)
J. A. LIGHTHIPE.
H. H. BARNES JR.
CHARLES E. SCRIBNER.

(Term expires July 31, 1916.)
F. S. HUNTING.
N. W. STORER.
FARLEY OSGOOD.

MANAGERS.

(Term expires July 31, 1915.)
COMFORT A. ADAMS.
J. FRANKLIN STEVENS.
WILLIAM B. JACKSON.
WILLIAM McCLELLAN

(Term expires July 31, 1916.)
H. A. LARDNER.
B. A. BEHREND.
PETER JUNKERSFELD.
L. T. ROBINSON.

(Term expires July 31, 1917.)
FREDERICK BEDELL.
BANCROFT GHERARDI.
A. S. McALLISTER.
JOHN H. FINNEY.

TREASURER.
GEORGE A. HAMILTON.

(Term expires July 31 1915.)

SECRETARY.
F. L. HUTCHINSON.

PAST-PRESIDENTS.—1884-1914.

*NORVIN GREEN, 1884-5-6.
*FRANKLIN L. POPE, 1886-7.
T. COMMERFORD MARTIN, 1887-8.
EDWARD WESTON, 1888-9.
ELIHU THOMSON, 1889-90.
*WILLIAM A. ANTHONY, 1890-91.
ALEXANDER GRAHAM BELL, 1891-2.
FRANK JULIAN SPRAGUE, 1892-3.
*EDWIN J. HOUSTON, 1893-4-5.
LOUIS DUNCAN, 1895-6-7.
FRANCIS BACON CROCKER, 1897-8.
A. E. KENNELLY, 1898-1900.
CARL HERING, 1900-1.
CHARLES P. STEINMETZ, 1901-2.
CHARLES F. SCOTT, 1902-3.
BION J. ARNOLD, 1903-4.
JOHN W. LIEB JR., 1904-5.
SCHUYLER SKAATS WHEELER, 1905-6.
SAMUEL SHELDON, 1906-7.
HENRY G. STOTT, 1907-8.
LOUIS A. FERGUSON, 1908-09.
LEWIS B. STILLWELL, 1909-10.
DUGALD C. JACKSON, 1910-11.
GANO DUNN, 1911-12.
RALPH D. MERSHON, 1912-13.
C. O. MAILLOUX, 1913-14.

*Deceased.

HONORARY SECRETARY.

RALPH W. POPE,
33 West 39th Street New York.

GENERAL COUNSEL.

PARKER and AARON,
52 Broadway, New York.

STANDING COMMITTEES

Revised to Oct. 1, 1914

EXECUTIVE COMMITTEE.

P. M. Lincoln, Chairman,
W. E. and M. Company, East Pittsburgh, Pa.
C. A. Adams, G. A. Hamilton,
H. H. Barnes, Jr., William McClellan,
B. A. Behrend, N. W. Storer.

FINANCE COMMITTEE

J. P. Stevens, Chairman,
1326 Chestnut St., Philadelphia, Pa.
H. H. Barnes, Jr. B. Gherardi.

LIBRARY COMMITTEE.

Samuel Sheldon, Chairman,
198½ Schermerhorn St., Brooklyn, N. Y.
B. Gherardi, Harold Pender,
F. L. Hutchinson, W. I. Slichter.

MEETINGS AND PAPERS COMMITTEE.

L. T. Robinson, Chairman,
General Electric Company, Schenectady, N. Y.
L. W. Chubb, H. H. Norris,
S. M. Kintner, C. P. Steinmetz,
and the chairmen of all technical committees.

EDITING COMMITTEE.

H. H. Norris, Chairman,
239 West 39th St., New York.
M. G. Lloyd, W. S. Rugg,
A. S. McAllister, W. I. Slichter.

BOARD OF EXAMINERS.

Maurice Coster, Chairman,
165 Broadway, New York.
Philander Betts, A. S. McAllister,
Henry Floy, John B. Taylor.

SECTIONS COMMITTEE.

H. A. Horner, Chairman,
Hamilton Court, 39th and Chestnut Streets, Philadelphia, Pa.
Frederick Bedell, W. A. Hall,
H. W. Flashman, F. D. Nims,
Charles F. Scott,
and the chairmen of all Institute Sections.

STANDARDS COMMITTEE.

A. E. Kennelly, Chairman,
Harvard University, Cambridge, Mass
C. A. Adams, Secretary,
Harvard University, Cambridge, Mass.
James Burke, W. H. Powell,
W. A. Del Mar, Charles Robbins,
H. W. Fisher, L. T. Robinson,
H. M. Hobart, E. B. Rosa,
P. Junkersfeld, C. E. Skinner,
G. L. Knight, J. M. Smith,
W. L. Merrill, H. G. Stott,
P. H. Thomas.

CODE COMMITTEE.

Farley Osgood, Chairman,
763 Broad Street, Newark, N. J.
J. C. Forsyth, George F. Sever,
H. B. Gear, H. O. Lacount,
H. N. Muller, C. E. Skinner,
A. M. Schoen, H. R. Sargent.

LAW COMMITTEE.

G. H. Stockbridge, Chairman,
165 Broadway, New York.
Charles L. Clarke, Paul Spencer,
C. E. Scribner, Charles A. Terry.

SPECIAL COMMITTEES

Revised to Oct. 1, 1914.

POWER STATIONS.

H. G. Stott, Chairman,
600 West 59th Street, New York.
W. S. Gorsuch, C. S. MacCalla,
J. H. Hanna, R. J. S. Piggott,
C. A. Hobein, E. F. Scattergood.
A. S. Loizeaux, Paul Spencer,
C. P. Uebelacker.

TRANSMISSION COMMITTEE.

P. H. Thomas, Chairman,
2 Rector St., New York.
E. J. Berg, V. D. Moody,
P. M. Downing, F. D. Nims,
A. R. Fairchild, F. W. Peek, Jr.,
F. A. Gaby, Harold Pender,
L. E. Imlay, K. C. Randall,
L. R. Lee, C. S. Ruffner,
G. H. Lukes, F. D. Sampson,
Ralph D. Mershon, P. W. Sothman,
W. E. Mitchell, C. E. Waddell,
J. E. Woodbridge.

RAILWAY COMMITTEE.

D. C. Jackson, Chairman,
248 Boylston Street, Boston, Mass.
A. H. Armstrong, E. B. Katte,
A. H. Babcock, Paul Lebenbaum,
E. J. Blair, W. S. Murray,
H. M. Brinckerhoff, Clarence Renshaw,
E. P. Burch, A. S. Richey,
H. M. Hobart, F. J. Sprague,
N. W. Storer.

PROTECTIVE APPARATUS.

[Not yet appointed.]

ELECTRIC LIGHTING COMMITTEE.

Clayton H. Sharp, Chairman,
556 East 80th St., N. Y.
J. W. Cowles, H. W. Peck,
E. P. Hyde, S. G. Rhodes,
P. Junkersfeld, E. B. Rosa,
A. S. Loizeaux, G. H. Stickney,
T. S. Perkins, C. W. Stone.

INDUSTRIAL POWER COMMITTEE.

D. B. Rushmore, Chairman,
General Electric Company Schenectady, N. Y.
A. C. Eastwood, J. P. Mallett,
Walter A. Hall, E. H. Martindale,
J. M. Hipple, W. L. Merrill,
G. H. Jones, J. A. Osborn,
C. D. Knight, A. G. Pierce,
J. C. Lincoln, H. A. Pratt.

TELEGRAPHY AND TELEPHONY COMMITTEE.

C. E. Scribner, Chairman,
463 West Street, New York.
C. L. Fortescue, William Maver, Jr.
H. M. Friendly, K. B. Miller,
A. H. Griswold, H. Mouradian,
F. B. Jewett, W. O. Pennell.
S. M. Kinter, Jr., J. B. Taylor,
J. L. Wayne.

COMMITTEE ON USE OF ELECTRICITY IN MINES.

Wilfred Sykes, Chairman,
Box 242, East Liberty, Pa.

F. E. Alexander, M. H. Gerry, Jr.
C. W. Beers, Charles Legrand,
W. W. Briggs, K. A. Pauly,
Graham Bright, G. B. Rosenblatt,
B. T. Viall.

COMMITTEE ON USE OF ELECTRICITY IN MARINE WORK

C. S. McDowell, Chairman.
Navy Yard, New York.

Maxwell W. Day, H. A. Horner,
W. L. R. Emmet, O. P. Loomis,
F. C. Hanker, D. M. Mahood,
H. L. Hibbard, Elmer A. Sperry,
Guy Hill, G. A. Pierce, Jr.,
F. W. Wood.

IRON AND STEEL INDUSTRY.

[Not yet appointed.]

ELECTROCHEMICAL COMMITTEE.

A. F. Ganz, Chairman.
Stevens Institute, Hoboken, N. J.

C. G. Schluederberg, C. F. Burgess,
W. R. Whitney, Lawrence Addicks,
Carl Hering, E. F. Price,
L. L. Summers.

ELECTROPHYSICS COMMITTEE.

J B. Whitehead, Chairman,
Johns Hopkins University, Baltimore, Md

Frederick Bedell, E. L. Nichols,
H. L. Blackwell, E. B. Rosa,
L. W. Chubb, H. J. Ryan,
W. S. Franklin, H. Clyde Snook.

RECORDS AND APPRAISALS OF PROPERTIES.

William B. Jackson, Chairman,
111 W. Monroe Street, Chicago, Ill.

Philander Betts, W. J. Norton,
William H. Blood, Jr., C. L. Pillsbury,
Fred A. Bryan, H. Spoehrer,
C. L. Cory, W. G. Vincent,
Clifton W. Wilder.

EDUCATIONAL COMMITTEE.

V. Karapetoff, Chairman.
Cornell University, Ithaca, N. Y.

E. J. Berg, A. S. Langsdorf,
F. L. Bishop, C. E. Magnusson,
C. R. Dooley, Charles F. Scott,
G. A. Hoadley, P. B. Woodworth.

PUBLIC POLICY COMMITTEE.

Calvert Townley, Chairman,
165 Broadway, New York.

H. W. Buck, H. A. Lardner,
Fredk. Darlington, William McClellan,
Gano Dunn, E. W. Rice, Jr.,
J. H. Finney, L. B. Stillwell,
H. G. Stott.

PATENT COMMITTEE.

Ralph D. Mershon, Chairman,
80 Maiden Lane, New York.

Bion J. Arnold, O. S. Schairer,
C. S. Bradley, C. E. Scribner,
Val. A. Fynn, F. J. Sprague,
John F. Kelly, C. A. Terry,
H. Ward Leonard, E. S. Northrup.

MEMBERSHIP COMMITTEE.

H. D. James, Chairman,
W. E. and M. Company, East Pittsburgh, Pa.

Markham Cheever, A. G. Jones,
E. L. Doty, S. C. Lindsay,
Walter A. Hall, Herbert S. Sands,
Max Hebgen, M. S. Sloan,
H. A. Horner, W. S. Turner,
P. B. Woodworth.

HISTORICAL MUSEUM COMMITTEE.

T. C. Martin, Chairman,
29 West 39th Street, New York.

John J. Carty, E. W. Rice, Jr.,
Charles L. Clarke, Charles F. Scott,
Louis Duncan, Frank J. Sprague.

U. S. NATIONAL COMMITTEE OF THE INTERNATIONAL ELECTROTECHNICAL COMMISSION

C. O. Mailloux, President,
20 Nassau Street, New York

F. B. Crocker, Vice-Pres., A. E. Kennelly, Sec.,
Harvard University, Cambridge, Mass.

C. A. Adams, E. B. Rosa,
B. A. Behrend, C. F. Scott,
James Burke, C. H. Sharp,
Louis Bell, C. E. Skinner,
J. J. Carty, Samuel Sheldon,
Gano Dunn, Charles P. Steinmetz,
H. M. Hobart, H. G. Stott,
J. W. Lieb, Elihu Thomson.
Philip Torchio.

INTERNATIONAL ELECTRICAL CONGRESS, SAN FRANCISCO, 1915.

EXECUTIVE COMMITTEE OF COMMITTEE ON ORGANIZATION.

Charles P. Steinmetz, Honorary President of Congress,
E. B. Rosa, Honorary Secretary of Congress,
H. G. Stott, Chairman,
600 West 59th Street, New York,
John W. Lieb, Jr., Vice-Chairman,
C. O. Mailloux, Chairman, Sub-Committee on International Relations,
A. E. Kennelly, Chairman, Sub-Committee on Program,
Henry A. Lardner, Chairman, Sub-Committee on Pacific Coast Relations,
H. H. Barnes, Jr., Chairman, Sub-Committee on Transportation,
George F. Sever, Chairman, Sub-Committee on Entertainment,
Preston S. Millar, Secretary-Treasurer and Chairman, Sub-Committee on Publicity. 556 East 80th Street, New York,
F. L. Hutchinson, Secretary, A. I. E. E. [*Ex Officio*].

COMMITTEE ON RELATIONS OF CONSULTING ENGINEERS.

L. B. Stillwell, Chairman,
100 Broadway, New York.

H. W. Buck, F. R. Ford,
Gano Dunn, F. N. Waterman.

COMMITTEE ON CODE OF PRINCIPLES OF PROFESSIONAL CONDUCT.

George F. Sever, Chairman,
13 Park Row, New York.

H. W. Buck, John F. Kelly,
Gano Dunn, Schuyler Skaats Wheeler.

EDISON MEDAL COMMITTEE.

Appointed by President for terms of five years.

Term expires July 31, 1919.
Charles F. Brush, William Stanley,
N. W. Storer.

Term expires July 31, 1918.
H. W. Buck, J. Franklin Stevens,
F. A. Scheffler.

Term expires July 31, 1917.
A. E. Kennelly, H. Ward Leonard,
Robert T. Lozier,

Term expires July 31, 1916
Frank J. Sprague
Schuyler Skaats Wheeler, Chairman,
Ampere, N. J.
W. D. Weaver.

Term expires July 31, 1915.
Elihu Thomson, J. W. Lieb, Jr.,
E. L. Nichols.

Elected by the Board of Directors from its own membership for terms of two years.

Term expires July 31, 1915.
H. H. Barnes, Jr., William McClellan,
A. S. McAllister.

Term expires July 31, 1916.
C. E. Scribner, C. O. Mailloux,
L. T. Robinson.

Ex-Officio.
P. M. Lincoln, President.
George A. Hamilton, Treasurer.
F. L. Hutchinson, Secretary.

INSTITUTE REPRESENTATIVES

ON BOARD OF AWARD, JOHN FRITZ MEDAL

Dugald C. Jackson, Ralph D. Mershon,
Gano Dunn, C. O. Mailloux.

ON BOARD OF TRUSTEES, UNITED ENGINEERING SOCIETY.

Gano Dunn. Charles E. Scribner.
H. H. Barnes, Jr.

ON LIBRARY BOARD OF UNITED ENGINEERING SOCIETY.

Samuel Sheldon, Harold Pender,
B. Gherardi, W. I. Slichter,
F. L. Hutchinson.

ON ELECTRICAL COMMITTEE OF NATIONAL FIRE PROTECTION ASSOCIATION.

The chairman of the Institute's Code Committee,
Farley Osgood.

ON ADVISORY BOARD OF AMERICAN YEAR-BOOK.

Edward Caldwell.

ON ADVISORY BOARD, NATIONAL CONSERVATION CONGRESS.

Calvert Townley.

ON COUNCIL OF AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

W. S. Franklin. G. W. Pierce.

ON CONFERENCE COMMITTEE OF NATIONAL ENGINEERING SOCIETIES.

Calvert Townley. William McClellan.

ON JOINT COMMITTEE ON ENGINEERING EDUCATION.

Charles F. Scott, Samuel Sheldon.

ON AMERICAN ELECTRIC RAILWAY ASSOCIATION'S COMMITTEE ON JOINT USE OF POLES.

Farley Osgood, F. B. H. Paine,
Percy H. Thomas.

ON NATIONAL JOINT COMMITTEE ON OVERHEAD LINE CONSTRUCTION.

Farley Osgood, F. B. H. Paine,
Percy H. Thomas.

ON NATIONAL COMMITTEE ON ELECTROLYSIS.

Bion J. Arnold, F. N. Waterman,
Paul Winsor.

ON BOARD OF MANAGERS, PANAMA-PACIFIC INTERNATIONAL ENGINEERING CONGRESS, 1915.

A. M. Hunt. J. G. DeRemer.
And the President and Secretary of the Institute.

LOCAL HONORARY SECRETARIES.

Guido Semenza. N. 10, Via S. Radegonda, Milan, Italy.
Robert Julian Scott. Christ Church, New Zealand.
L. A. Herdt, McGill Univ., Montreal Que.
Henry Graftio, St. Petersburg, Russia.
Clare F. Beames, Bangalore, Mysore Province. India,
Richard O. Heinrich, Genest-str. 5 Schoeneberg, Berlin, Germany.
A. S. Garfield, 67 Avenue de Malakoff, Paris, France.

LIST OF SECTIONS

Atlanta, chairman, A. M. Schoen; secretary, H. M. Keys, Southern Bell Tel. & Tel. Co., Atlanta, Ga.

Baltimore, chairman, J. B. Whitehead; secretary, L. M. Potts, Industrial Building, Baltimore, Md.

Boston, chairman, George W. Palmer, Jr.; secretary, Harry F. Thomson, Massachusetts Institute of Technology, Boston, Mass.

Chicago, chairman, E. W. Allen; secretary, W. J. Norton, 112 W. Adams Street, Chicago, Ill.

Cleveland, chairman, A. C. Eastwood; secretary, R. E. Scovel, 1663 East 86th Street, Cleveland, Ohio.

Detroit-Ann Arbor, chairman, H. H. Norton; secretary, Ray K. Holland, Cornwell Building, Ann Arbor, Mich.

Fort Wayne, chairman, L. D. Nordstrum; secretary, J. J. A. Snook, 1117 Fairfield Avenue, Ft. Wayne, Ind.

Indianapolis-Lafayette, chairman, O. S. More; secretary, G. B. Schley, 908 Hume-Mansur Building, Indianapolis, Ind.

Ithaca, chairman, E. L. Nichols; secretary, George S. Macomber, Cornell University, Ithaca, N.Y

Los Angeles, chairman, C. G. Pyle; secretary, Edward Woodbury, Pacific Lt. & Pr. Company, Los Angeles, Cal.

Lynn, chairman, W. H. Pratt; secretary, F. S. Hall, General Electric Co., Lynn, Mass.

Madison, chairman, J. W. Shuster; secretary, F. A. Kartak, Univ. of Wisconsin, Madison, Wis.

Mexico,

Milwaukee, chairman, L. L. Tatum; secretary, W. J. Richards, National Brake and Electric Co. Milwaukee, Wis.

Minnesota, chairman, Leo H. Cooper; secretary, Emil Anderson, 1236 Plymouth Bldg., Minneapolis, Minn.

Panama, chairman, Hartley Rowe; secretary, Clayton J. Embree, Balboa Heights, C.Z.

Philadelphia, chairman, H. F. Sanville; secretary, W. F. James, 1115 North American Bldg., Philadelphia, Pa.

Pittsburgh, chairman, J. W. Welsh; secretary, Charles R. Riker, Electric Journal, Pittsburgh, Pa.

Pittsfield, chairman, W. W. Lewis; secretary, M. E. Tressler, General Electric Company, Pittsfield, Mass.

Portland, Ore., chairman, R. F. Monges; secretary, Paul Lebenbaum, 45 Union Depot, Portland, Ore.

St. Louis, chairman, F. J. Bullivant; secretary, A. McR. Harrelson, Emerson Electric Mfg, Co. St. Louis, Mo.

San Francisco, chairman, C. J. Wilson; secretary, A. G. Jones, 819 Rialto Building, San Francisco, Cal.

Schenectady, chairman, H. M. Hobart; secretary, F. S. Wheeler, Gen. Elec. Co., Schenectady, N. Y.

Seattle, chairman, S. C. Lindsay; secretary, E. A. Loew, University of Washington, Seattle, Wash.

Spokane, chairman, J. W. Hungate; secretary, L. N. Rice, Parsons Hotel, Spokane, Wash.

Toledo, chairman, George E. Kirk; secretary, Max Neuber, Cohen, Friedlander & Martin, Toledo, O.

Toronto, chairman, D. H. McDougall, secretary, H. T. Case, Continental Life Bldg., Toronto, Ont.

Urbana, chairman, I. W. Fisk; secretary, P. S. Biegler, University of Illinois, Urbana, Ill.

Vancouver, chairman, E. M. Breed; secretary, L. G. Robinson, 1003 Holden Building, Vancouver, B. C.

Washington, D.C., chairman, C. B. Mirick; secretary, C. A. Peterson, Treasury Department, Washington, D. C.

LIST OF BRANCHES

Agricultural and Mechanical College of Texas, chairman, D. B. Pickens; secretary, E. C. Rack, A & M. College, College Station, Tex.

Arkansas, Univ. of., chairman, S. S. McGill; secretary, M. B. Roys, Univ. of Arkansas, Fayetteville Ark.

Armour Institute, chairman, E. L. Nelson; secretary, T. C. Bolton, Armour Inst. Tech., Chicago, Ill.

Bucknell University, chairman, F. O. Schnure; secretary, J. M. Hillman, Bucknell University, Lewisburg, Pa.

California, Univ. of., chairman, L. R. Chilcote; secretary, E. S. Meddaugh, 2521 Channing Way, Berkeley, Cal.

Cincinnati, Univ. of., chairman, M. L. Harned; secretary, A. C. Perry, University of Cincinnati, Cincinnati, O.

Clemsom Agricultural College, chairman, F. J. Jervey; secretary, F. H. McDonald, Clemson College, S. C.

Colorado State Agricultural College, chairman, L. M. Klinefelter; secretary, R. K. Havighorst, Colorado State Agricultural College, Fort Collins, Colo.

Colorado, Univ. of., chairman, Philip S. Borden; secretary, Charles S. Miller, University of Colorado, Boulder, Colo.

Georgia School of Technology,

Highland Park College, chairman, Clyde Prussman; secretary, Ralph R. Chatterton, Highland Park College, Des Moines, Iowa.

Idaho, University of.,

Iowa State College, chairman, Earle G. Nichols; secretary, P. A. Robbins, Iowa State College, Ames, Iowa.

Iowa, Univ. of., chairman, J. H. Scanlon; secretary, A. H. Ford, University of Iowa, Iowa City, Ia.

Kansas State Agr. Col., chairman, L. O'Brien; secretary, W. C. Lane, Kansas State Agric. Col., Manhattan, Kan.

Kansas, Univ. of., chairman, H. C. Hansen; secretary, L. M. Bocker, Univ. of Kansas, Lawrence, Kansas.

Kentucky, State Univ. of., chairman, Harry Y. Barker; secretary, G. F. Campbell, 345 South Limestone Street, Lexington, Ky.

Lafayette College, chairman, R. McManigal; secretary, W. J. English, Jr., Lafayette College, Easton, Pa.

Lehigh University, chairman, N. F. Matheson; secretary, F. C. Brockman, Lehigh University, S. Bethlehem, Pa.

Lewis Institute, chairman, A. H. Fensholt; secretary, Fred A. Rogers, Lewis Institute, Chicago, Ill.

Maine, Univ. of., chairman, C. M. Kelly; secretary, E. L. Getchell, University of Maine, Orono, Maine.

Michigan, Univ. of., chairman, H. A. Enos; secretary, H. W. Stubbs, University of Michigan, Ann Arbor, Mich.

Missouri, Univ. of., chairman, E. W. Kellogg; secretary, K. Atkinson, University of Missouri, Columbia, Mo.

Montana State Col., chairman, John M. Fiske; secretary, J. A. Thaler, Montana State College, Bozeman, Mont.

Nebraska, Univ. of., chairman, Olin J. Ferguson; secretary, V. L. Hollister, Station A, Lincoln, Nebraska.

New Hampshire Col.,

North Carolina Col. of Agr. and Mech. Arts, chairman, Wm. H. Browne, Jr., secretary, James Fontaine, West Raleigh, N. C.

Ohio Northern Univ., chairman, A. B. Curtis; secretary, W. F. Schott, 426 South Union Street, Ada, Ohio.

Ohio State Univ., chairman, Leslie J. Harter; secretary, Robert C. Schott, Ohio State Univ., Columbus, Ohio.

Oklahoma Agricultural and Mech. Col., chairman, A. P. Little; secretary, Quentin Graham, 118 Husband St., Stillwater, Okla.

Oklahoma, Univ. of., chairman, R. D. Evans; secretary, L. J. Hibbard, Univ. of Oklahoma, Norman, Okla.

Oregon Agr. Col., chairman, A. O. Manigold; secretary, I. L. Olmstead, Oregon Agric. Col., Corvallis, Ore.

Penn State College, chairman, A. D. Shultz; secretary, A. T. McNeile, State College, Pa.

Pittsburgh, University of., chairman, B. E. O'Hagan; secretary, George Hickman, University of Pittsburgh, Pittsburgh, Pa.

Purdue Univ., chairman, L. W. Spray; secretary, R. E. Tafel, Purdue University, Lafayette, Ind.

Rensselaer Poly. Inst., chairman, W. J. Williams; secretary, H. F. Wilson, Rensselaer Poly. Institute, Troy, N. Y.

Rose Polytechnic Inst., chairman, Charles F. Harris; secretary, Claude A. Lyon, 1331 Liberty Avenue, Terre Haute, Ind.

Rhode Island State Col., chairman, W. C. Miller; secretary, P. M. Randall, Jr., Rhode Island State College, Kingston, R. I.

Stanford Univ., chairman, G. L. Beaver; secretary, H. J. Scholz, Stanford University, Cal.

Syracuse Univ., chairman, W. P. Graham; secretary, R. A. Porter, Syracuse University, Syracuse, N. Y.

Texas, Univ. of., chairman, Joseph W. Ramsey; secretary, J. A. Correll, University of Texas, Austin, Tex.

Throop College of Technology, chairman, W. L. Newton; secretary, A. W. Wells, Throop Poly. Institute, Pasadena, Cal.

Virginia, Univ. of., chairman, Walter S. Rodman; secretary, H. Anderson, Jr., 1022 West Main St., Charlottesville, Va.

Wash., State Col. of., chairman, M. K. Akers; secretary, H. V. Carpenter, State Coll. of Wash., Pullman, Wash.

Washington Univ., chairman, R. D. Duncan, Jr.; secretary, C. C. Hardy, Washington University, St. Louis, Mo.

Washington, Univ. of., chairman, H. W. McRobbie; secretary, B. B. Bessesen, Univ. of Washington, Seattle, Wash.

Worcester Poly. Inst., chairman, Frank Aiken; secretary, A. B. R. Prouty, Worcester Poly. Inst., Worcester, Mass.

Yale University, chairman, F. M. Doolittle; secretary, W. L. Kenly, New Haven, Conn.

SECTION II

PROCEEDINGS

of the

American Institute

of

Electrical Engineers

Papers, Discussions and Reports

CONTENTS OF SECTION II

PROCEEDINGS

OF THE

American Institute

OF

Electrical Engineers.

Published monthly by the A. I. E. E.. at 33 W. 39th St., New York, under the supervision of

THE EDITING COMMITTEE

GEORGE R. METCALFE, Editor

Subscription. $10.00 per year for all countries to which the bulk rate of postage applies,
All other countries $12.00 per year.
Single copy $1.00
Subscriptions must begin with January issue.

Changes of advertising copy should reach this office by the 15th of the month, for the issue of the following month.

Vol. XXXIII **November, 1914** No. 11

Institute Meeting in New York November 13, 1914

The 301st meeting of the American Institute of Electrical Engineers will be held in the Auditorium of the Engineering Societies Building, 33 West 39th Street, New York, on Friday, November 13, at 8:15 p.m.

Two papers will be presented at this meeting, as follows: *Graphic Method for Speed-Time and Distance-Time Curves,* by E. C. Woodruff, and *The Corona Produced by Continuous Potentials,* by Stanley P. Farwell. The first paper presents a simple method for obtaining speed-time and distance-time curves by means of charts, which avoids the usual step by step process with its tedious calculations. The second paper deals with an experimental investigation of the corona around small wires produced by continuous potentials up to 15,000 volts. Both of these papers are published elsewhere in this issue of the PROCEEDINGS and reprints may be obtained on application to the Secretary.

After the close of the technical session a smoker will be held.

Indefinite Postponement of International Electrical Congress

The war rendering it improbable that adequate international representation can be secured at the International Electrical Congress which it was proposed to hold in San Francisco in September, 1915, the Board of Directors of the American Institute of Electrical Engineers, acting upon recommendation of the Executive Committee of the Congress Committee on Organization, has declared the Congress to be postponed until such time as it may be found practicable to hold an international electrical congress in the United States of America.

In announcing this postponement, the Congress Executive Committee expresses its thanks to the many individuals and organizations whose cooperation it has enjoyed in its organization work. In due course all who have agreed to present papers before the Congress will be advised of the postponement, and all subscriptions to the Congress by members will be refunded in full.

PRESTON S. MILLAR,
secretary-treasurer,
Executive Committe of Committee on Organization.

Oct. 10, 1914.

Directors' Meeting October 9, 1914

The regular monthly meeting of the Board of Directors of the Institute was held in New York on Friday, October 9, 1914, at 3:30 p.m.

There were present: President Paul M. Lincoln, Pittsburgh, Pa., Past-President C. O. Mailloux, New York; Vice-Presidents Charles E. Scribner, New York, N. W. Storer, Pittsburgh, Pa., Farley Osgood, Newark, N. J.; Managers C. A. Adams, Cambridge, Mass., J. Franklin Stevens, Philadelphia, Pa., William McClellan, Bancroft Gherardi and A. S. McAllister, New York, B. A. Behrend, Boston, Mass.,

L. T. Robinson, Schenectady, N. Y., John H. Finney, Washington, D. C.; Treasurer George A. Hamilton, Elizabeth, N. J., and Secretary F. L. Hutchinson, New York.

President Lincoln announced the appointment of the following committees: Law, G. H. Stockbridge, chairman; Power Stations, H. G. Stott, chairman; Records and Appraisals of Properties, William B. Jackson, chairman; also the appointment of Mr. T. P. Strickland, Sydney, N. S. W., as Local Honorary Secretary for Australia.

The action of the Finance Committee in approving monthly bills amounting to $8,974.07 was ratified.

The report of the Finance Committee submitting the annual budget covering the proposed expenditures of the Institute during the appropriation year beginning October 1, 1914, amounting to $106,950.00. was approved, and the budget was adopted.

Upon the petition of 32 Institute members in Rochester, N. Y., and the adjacent territory, and with the approval of the chairman of the Sections Committee, authority was granted for the organization of a Section in Rochester.

Authority was also granted for the establishment of a University Branch at the University of North Carolina, Chapel Hill, N. C., in response to a petition from Professor P. H. Daggett, an Institute member, connected with the department of electrical engineering at the university.

Upon the recommendation of the Board of Examiners, the Board of Directors transferred one member of the Institute to the grade of Fellow and seven to the grade of Member, elected six applicants as Members and 40 as Associates, and ordered the enrolment of 55 students, in accordance with the lists printed in this issue of the PROCEEDINGS.

The Executive Committee of the Committee on Organization of the International Electrical Congress recommended that, in view of the improbability of carrying out a congress which would be international in scope and character in 1915, the proposed Electrical Congress be indefinitely postponed, and the following resolutions were adopted:

Whereas, the war in Europe renders it inexpedient to hold an International Electrical Congress in San Francisco during the year 1915, it is

Resolved that the Congress be postponed; that as soon as it shall be deemed advisable a new date shall be selected by the American Institute of Electrical Engineers for holding the Congress in the United States; that the Executive Committee of the Committee on Organization be continued and its records be preserved; and be it further

Resolved that, having underwritten the Congress to the extent of $15,000, the Board of Direcsors now appropriate such sum as may be necessary, not to exceed $1,500, to meet a deficit in the Congress funds, and to permit the Executive Committee of the Committee on Organization to refund to all members in full the payments they have made to the Congress funds, and be it further

Resolved that the Secretary of the Executive Committee be instructed to make suitable announcement of the postponement of the Congress, and be it further

Resolved that the thanks of the Institute for valuable work be extended to the Institute's local representatives abroad, and to the members of the Committee on Organization, its Executive Committee and sub-committees, who have labored for the success of the Congress.

A considerable amount of other business was transacted by the Board, reference to which will be found under appropriate headings in this and future issues of the PROCEEDINGS.

The Value of Membership in the American Institute of Electrical Engineers

Have you ever thought what determines the standing of an engineer? Some engineers have attained fame and prominence in their profession and are well known. These men represent the leaders in the profession. Other men have more or less prominence given them by virtue of the positions which they hold. It is usually conceded that a man who holds a leading position on the staff of a large organization must have ability or he would not have been appointed to this position.

By far the greater number of engineers,

particularly the younger men, have not yet received a "handle" to their name. Their reputation is dependent primarily upon the opinion formed by the engineers who know them and are associated with them.

In discussing the merits of various electrical engineers, the list of members of the American Institute of Electrical Engineers is usually referred to. There is a general feeling among some of the older engineers that a man is lacking in enterprise and willingness to help advance his profession, who does not associate himself with his own national society. The writer has been present at discussions where the name of an engineer has been mentioned who was not personally known to those present. If his name did not appear in the list of his national society, the question was always raised as to why he was not a member. The chief engineer of a very large company made the following statement in a recent letter to the writer:

"Merely to have one's name in the Institute list is of great importance. I am often asked to recommend engineers to bankers and others who wish to obtain certain special services. To refresh my recollection I very often refer to the Institute list, and I know that this list is used in this and similar ways constantly."

Many an engineer, especially the more successful engineer, shows keen foresight in recognizing early in his practise the importance of associating himself with the national body. Mr. Ralph W. Pope, honorary secretary of the Institute, writes as follows:

"Engineers who allow their membership to lapse through carelessness or adverse circumstances, subsequently recognize their loss and apply for reinstatement, and pay considerable lump sums in order to retain their original date of election and transfer. During the last three years there have been reinstatements and payment of back dues covering from three to fourteen years in the following amounts—$150, $115, and two each of $70, $60 and $50. No doubt there have also been hundreds of cases where members have had a hard struggle to make both ends meet, but have maintained their standing in the Institute because membership is a real asset."

An engineer who hesitates to join the Institute because of the expense, should consider that many men struggle through their four years of college life under great hardship in order to obtain not only the information and training which a course like this gives, but to be able to write after their names the symbols of a degree. Such men realize the value of being known as a technical graduate. The Institute is merely a post-graduate course for these men. If to be an alumnus of a technical school or university is of value to a man in establishing his standing among his colleagues, why should he hesitate to spend the small amount of money necessary to be associated with these colleagues in his own national society?

H. D. James, chairman,
Membership Committee.

A. I. E. E. Meeting in New York October 9, 1914

The 299th meeting of the Institute was held in the auditorium of the Engineering Societies Building, New York, on Friday evening, October 9, 1914.

President Paul M. Lincoln called the meeting to order at 8:20 p.m., and asked Dr. A. S. McAllister, in the absence of the authors, to present the first paper of the program, *Protective Reactances for Feeder Circuits of Large City Power Systems*, by Messrs. James Lyman, Leslie L. Perry, and A. M. Rossman. The second paper, *Use of Reactance with Synchronous Converters*, was then presented by the author, Mr. J. L. McK. Yardley, and the two were discussed together.

Among those who took part in the discussion were Messrs. D. B. Rushmore, Philip Torchio, H. W. Buck, J. J. Frank, N. W. Storer, H. Goodwin,

Jr., George T. Hanchett, Carl J. Fechheimer, Selby Haar and A. S. McAllister.

The two papers that were discussed at the meeting are reprinted in this issue of the PROCEEDINGS.

A. I. E. E. Meeting in Philadelphia October 12, 1914

The 300th meeting of the Institute was held at Philadelphia, in the Engineering Building of the University of Pennsylvania, on October 12, 1914. The program for this meeting had been arranged by the Institute's Committee on the Use of Electricity in Marine Work.

President Paul M. Lincoln, in opening the first session at 2:00 p.m., called attention to the fact that the day was almost exactly the 30th anniversary of the first meeting of the Institute, held in Philadelphia in 1884.

The first paper on the program was *Submarine Signaling*, by Mr. R. F. Blake, describing the Fessenden submarine oscillator. The paper was presented by Mr. H. J. W. Fay. Those who took part in the discussion were Messrs. W. S. Franklin, E. A. Sperry, G. A. Hoadley, H. A. Hornor, G. Breed, J. B. Taylor, V. Karapetoff and H. J. W. Fay.

Mr. H. A. Hornor then presented his paper, entitled *Electrical Equipment of the Argentine Battleship "Moreno,"* which was discussed by Messrs. H. B. Hibbard, E. A. Sperry, M. W. Day, G. A. Pierce, Jr., C. S. McDowell, L. C. Porter, and others.

Following the dinner at the Hotel Normandie, the evening session was held. After some further discussion of Mr. Hornor's paper, the paper by Mr. F. H. Newell, *Electrical Features of the United States Reclamation Service*, was presented by Professor George A. Hoadley. The discussion was participated in by Messrs. Hoadley, P. M. Lincoln, Paul Spencer, R. W. Pope, J. E. Kershner, H.A. Hornor, V. Karapetoff, Carl Hering and H. Goodwin, Jr.

Lighting to be Discussed by New York Section, American Electrochemical Society

The New York Section of the American Electrochemical Society extends a hearty invitation to all members of the Institute to attend the meeting of the Section on November 12, 1914, at the Chemists Club, 52 East 41st Street, beginning at 8 p.m. The evening will be devoted to an interesting program of papers on "The Art of Lighting," including electric incandescent, electric arc, and electric tube lighting. Members of the American Gas Institute and the Illuminating Engineering Society have also been invited to attend.

Recommended for Transfer to the Grade of Member, October 1, 1914

The Board of Examiners, at its regular monthly meeting on October 1, 1914, recommended the following Associates for transfer to the grade of Member. Any objection to these transfers should be filed at once with the Secretary.

ATKINSON, RALPH WALDO, Asst. to Chief Engineer, Standard Underground Cable Co., Perth Amboy, N. J.

HATCH, EDWIN GLENTWORTH, Electrical and Mechanical Engineer, New York, N. Y.

JONES, EDWARD CROSBY, Electrical Engineer, c/o Crocker-Wheeler Co., Ampere, N. J.

MIDDLETON, W. IRVING, Electrical Engineer, Testing Dept., Simplex Wire & Cable Co., Cambridge, Mass.

MITCHELL, GUY K., Proprietor, Standard Electric & Elevator Co., Baltimore, Md.

RUTTENCUTTER, A. T., Electrical Engineer, Rio de Janeiro Tramway, Light & Power Co. Ltd., Rio de Janeiro, Brazil.

Transferred to the Grade of Fellow October 9, 1914

The following member was transferred to the grade of Fellow of the Institute at the meeting of the Board of Directors on October 9, 1914.

EDSTROM, J. SIGFRID, Managing Director, Allmanna Svenska Electric Co., Westeras, Sweden.

Transferred to the Grade of Member October 9, 1914

The following Associates were transferred to the grade of Member of the Institute at the meeting of the Board of Directors on October 9, 1914.

BLAKESLEE, DORAF WILMOT, Superintending Erector, Kerr Turbine Co., Wellsville, N. Y.

CONNETTE, EDWARD G., President, International Railway Co., Buffalo, N. Y.

FRANK, KARL GEORG, Representative, Siemens & Halske A. G. & Siemens-Schuckert Werke of Berlin, New York, N. Y.

MOURADIAN, H., Engineer of Transmission and Protection, Bell Telephone Co. of Penna., Philadelphia, Pa.

MURPHY, PATRICK J., Electrical Engineer, Ford, Bacon & Davis, New York, N. Y.

PILLSBURY, CHARLES L., Consulting Engineer, Minneapolis, Minn.

SWENSON, S. O., Electrical Engineer, Kansas City Terminal Ry. Co., Kansas City, Mo.

Members Elected October 9, 1914

DUNCAN, THOMAS C., City Electrical Engineer and Supt. Light & Telephone Depts., Prince Rupert City Electrical Department, Prince Rupert, B. C.

FLEMING, ARTHUR P. M., Superintendent, Transformer, Winding & Insulating Dept., British Westinghouse Electric & Mfg. Co., Ltd., Trafford Park, Manchester, England.

MANNING, JAMES HENRY, Stone & Webster Engineering Corp., 147 Milk St., Boston, Mass.

RUNYON, FREDERICK O., Consulting Engineer, Runyon & Carey, 845 Broad St., Newark, N. J.

SOUTHGATE, HUGH MACLELLAN, Manager, Government Office, Westinghouse Electric & Mfg. Co., Washington, D. C.; res., Chevy Chase, Md.

SPENCER, CLARENCE G., Resident Electrical Engineer, Chile Exploration Co., Tocopilla, Chile.

Associates Elected October 9, 1914

BARCLAY, ROBERT HAMILTON, Assistant Engineer, Electrical Dept., Kansas City Terminal Ry. Co., Kansas City, Mo.

BEEBE, JOHN CLEAVELAND, Power and Pumping Engineer, Idaho Irrigation Co. Ltd., Richfield, Idaho.

BELLMAN, JOHN J., Electrical Engineer, 220 W. 42nd St., New York, N. Y.

BLAIR, CHARLES A., Chief Electrician, Los Angeles City School District; res., 4619 Russell Ave., Los Angeles, Cal.

BRATTLE, WILFRED P., Assistant to Chief Engineer, Department of Telephones, Regina, Sask.

BRIGGS, LEROY E., Staff Engineer, Laboratory of Thomas A. Edison, W. Orange; res., 35 North Maple Ave., E. Orange, N. J.

BURNETT, JOHN JOSEPH, *E. E.*, Junior Railway Engineer, Public Service Commission, New York; res., 58 Hooper St., Brooklyn, N. Y.

COYLE, FRANCIS B., Electrician, The Panama Canal, Ancon, C. Z.

DUBOSE, MCNEELY, Erecting Engineer, Riegos y Fuerza del Ebro, Seros Power House, Apartado 14, Lerida, Spain.

FEUCHTER, ROY J., Engineering Dept., National Carbon Co., Cleveland; res. 1491 Ridgewood Ave., Lakewood, Ohio.

GIERSCH, RICHARD FREDERICK, JR., Erecting Engineer, Riegos y Fuerza del Ebro, Seros Power House, Apartado 14, Lerida, Spain.

HADLEY, FRANK ELLSWORTH, Operator, Cambridge Electric Light Co., Cambridge; res., 7 Charles St., Boston, Mass.

HAMON, CHESTER A., Electrical Tester, Westinghouse Electrical & Mfg. Co., E. Pittsburgh, res., 439 South Ave., Wilkinsburg, Pa.

HENK, PERCY VICTOR, Electrical Engineer, Australian General Electric Co., 217 Clarence St., Sydney N. S. W., Australia.

HODGE, WILLIAM E., Deputy Superintendent Street Lighting, City Hall, Springfield, Mass.

HOPE, LAPSLEY W., Superintendent, Adams Hill Corp., Eureka, Nev.

*HORLE, ALBERT M., Electrical Foreman, Panama Canal, Cristobal, C. Z.

*HUNT, NOAH HOUSTON, Chief Electrician, Chapman Engineering Co., Texas City, Tex.

JACOBSEN, HUGO W., Electrician, Division of Erection, Panama Canal, Gatun, C. Z.

JEALOUS, ARTHUR R., Assistant Works Manager, Clark Thread Co., Newark, N. J.

KOMURO, TAIJI, Electro-chemical Engineer, Yokohama Electric Wire Works, Yokohama, Japan.

LEONARD, LIONEL DOUGLAS, Electrical Engineer, Victoria Falls & Transvaal Power Co., Cleveland, Transvaal, S. Africa.

LEWIS, L. W., Electrical Draftsman, Panama Canal, Balboa, C. Z.

*LLOYD, AUSTIN MCL., Brush-testing Laboratory, National Carbon Co.; res., 1953 W. 100th St., Cleveland, O.

*MCEACHRON, KARL B., Ohio Northern University, Ada, Ohio.

MCRAE, DONALD MCL., Lineman, City Light & Power Co.; res., 375 College Ave., Winnipeg, Man.

MEDEIROS, ANNIBAL DE BARCELLOS, Student, Pratt Institute; res., 231 Ryerson St., Brooklyn, N. Y.

MILLER, ARTHUR ROSS, Engineering Dept., National Carbon Co.; res., 1346 W. 112th St., Cleveland, O.

MOULTON, SETH A., Consulting Engineer, 120 Exchange St., Portland, Me.

*MULLEN, FRANK B., Engineering Dept., New York Telephone Co., 15 Dey St., New York, N. Y.

PARKER, SAMUEL R., Assistant Engineer, Saskatchewan Government Telephones, Regina, Sask.

SCHUAKE, EDW. W., Wireman, The Panama Canal, Miraflores Locks; res., Corozal, C. Z.

SHIRAKI, KOJI, Electrical Engineer, Kinugawa Hydro-Electric Power Co., Tokyo, Japan.

SHIRLEY, ALBERT A., Commercial Engineer, General Electric Co., Schenectady, N. Y.

STRATEMEYER, EDWIN A., Assistant Engineer, Allis-Chalmers Mfg. Co. Bullock Works; res. 427 Warner St., Cincinnati, O.

*TAKATA, NINA I., 96 Ishiimura, Kobe, Japan.

THOMPSON, C. G., Station Engineer, Empire Power Plant, Empire, C. Z.

THOMSON, ANDREW, Assistant Engineer, Invercargill Power House; res., 78 Leet St., Ivercargill, New Zealand.

WILLIAMS, RICHARD A., Electrical Draftsman, Pacific Light & Power Corp.; res., 1344 Exposition Blvd., Los Angeles, Cal.

WILLIAMSON, ROBERT W., Electrician, Alabama Power Co., 1025 S. 28th St., Birmingham, Ala.

Total 40.

*Former enrolled Students.

Applications for Election

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before November 30, 1914.

Adams, C. C., Detroit, Mich.
Anger, R. E. Detroit, Mich.
Arikawa, A., Fukushimaken, Japan.

Bahm, J. F., Schenectady, N. Y.
Beasley, T. E., Bound Brook, N. J.
Bell, H. P., Oakland, Cal.
Biggs, R. N., Auckland, N. Z.
Bogardus, L. R., Detroit, Mich.
Buckley, J. V., Schenectady, N. Y.
Burgess, D., Detroit, Mich.
Cable, R. J., Detroit, Mich.
Capen, W. H., New York, N. Y.
Carten, J W., Detroit, Mich.
Clewell, C. E. (Member), Phila., Pa.
Cottle, G. T., Newark, N. J.
Crabtree, A. D., Clanton, Ala.
Craig, C. W., Jr., Philadelphia, Pa.
Cram, W. C., Jr., Birmingham, Ala.
Dixon, A. F., New York, N. Y.
Edgar, G. E., Groton, Conn.
Eldredge, M., Bombay, India
Felton, J. G., Gloversville, N. Y.
Field, F. E., State College, Pa.
Flaccus, G. W., Pittsburgh, Pa.
Frank, L. H., Wheeling, W. Va.
Freund, O. A., New York, N. Y.
Gibson, A. D., Rockwell City, Ia.
Gracey, Detroit, Mich.
Griswold, S. A., Hartford, Conn.
Heintze, E. C., Seattle, Wash.
Hersom, F. C., Boston, Mass.
Hodge, J., Detroit, Mich.
Ivens, J., New York, N. Y.
Jacobson, M., New York, N. Y.
Johnston, R. A., E. Pittsburgh, Pa.
Keith, A., Wyandotte, Mich.
Kilcoyne, F. R., Detroit, Mich.
Koerber, G. A., Newark, Del.
Koo, K. P., Schenectady, N. Y.
Lakin, C. E., Detroit, Mich.
Lawson, J. T. (Member), Newark, N. J.
Loef, J. W., Handley, Texas.
Lowry, E. A., Guelph, Ont.
Lundgren, L. (Member), Portland, Ore.
Lyle, F. W., Lynn, Mass.
McNaughtan, J. P., Detroit, Mich.
Moore, W. W., Detroit, Mich.
Mortensen, M. T., Detroit, Mich.
Murphy, E. S., Detroit, Mich.
Nicol, D. S., Montreal, Quebec
Norgren, C. A., Omaha, Neb.
Nowaski, G. W., Detroit, Mich.
Orcutt, G. H., Wyandotte, Mich.
Parker, K., Buffalo, N. Y.
Payette, P. L., Wyandotte, Mich.
Payne, R. T., Gatun, C. Z.
Plasko, J. G., Detroit, Mich.
Purdy, H. H., Detroit, Mich.
Pyle, L. N., Detroit, Mich.
Raab, H. F., Johnstown, Pa.
Reid, W., Clanton, Ala.
Rich, B. C., Detroit, Mich.
Richards, W. A., Windsor, Ont.
Roach, A. E., Windsor, Ont.
Robinson, E. W., Walkerville, Ont.
Robinson, G. L., Detroit, Mich.
Rutter, A. A., Detroit, Mich.
Schurig, O. R., Boston, Mass.
Shaw, H. J., Detroit, Mich.
Smith, A. C., (Member), Buffalo, N. Y.
Smith, M. A., Jr., Durham, N. C.
Spaulding, J. G., Detroit, Mich.
Steed, R. L., Detroit, Mich.
Steinberg, E. J., Milwaukee, Wis.
Steinmetz, F. E., Detroit, Mich.
Stevens, C. T., River Rouge, Mich.
Talbot, H. L., Oswego, Ore.
Taylor, N. S., E. Pittsburgh, Pa.
Ten Brook, R. W., Detroit, Mich.
Terry, C. W., Detroit, Mich.
Tiemann, W. O., Detroit, Mich.
Thomas, H. C., E. Pittsburgh, Pa.
Thomson, R. D. (Member), Burlington, Vt.
Tucker, F. N., Chicago, Ill.
Turner, W., Detroit, Mich.
Voorhess, C. R., Dearborn, Mich.
White, D. E., Seattle, Wash.
Willmore, H. E., Jr., Chicago, Ill.
Ziegler, C. E., Buffalo, N. Y.

Students Enrolled October 9, 1914

6695 Dickinson, C. R., Univ. of Ala.
6696 Glasly, J. B., Drexel Institute
6697 Dodds, J. M., Univ. of Wash.
6698 Beacock, V. A., Univ. of Toronto
6699 Van Duyn, C. H., Univ. of Ore.
6700 Watson, J. L., Univ. of Oregon
6701 Beebe, F. A., Univ. of Oregon
6702 Howard, T. W., Univ. of Oregon
6703 Fraser, C.M., Ohio Northern Univ.
6704 Sorensen, B., Univ. of Washington
6705 Gilmore, D., Univ. of Washington
6706 Burbank, S. R., Univ. of Wash.
6707 Stoppelmann, F.H., Univ. of Wash.
6708 Ryan, F. M., Univ. of Wash.
6709 Aleshouskas, J.W., Bucknell Univ.

6710 Gdaniec, J. F., Bucknell Univ.
6711 Irland, G. A., Bucknell Univ.
6712 Curfman, H. M., Univ. of Kansas
6713 Truesdell, S. A., Univ. of Kansas
6714 Arnold, G. B., Univ. of Kentucky
6715 Aud, J. G., Univ. of Kentucky
6716 Barker, H. Y., Univ. of Kentucky
6717 Barth, A. E., Univ. of Kentucky
6718 Batsel, M. C., Univ. of Kentucky
6719 Blackburn, A. R., Univ. of Ky.
6720 Brooke, M., Univ. of Kentucky
6721 Bolling, J. E., Univ. of Kentucky
6722 Campbell, G. F., Univ. of Ky.
6723 Caywood, L. B., Univ. of Ky.
6724 Courtney, S. N., Univ. of Ky.
6725 Crawley, W. P., Jr., Univ. of Ky.
6726 Croan, W. B., Univ. of Kentucky
6727 Eichhorn, T. F., Univ. of Ky.
6728 Evans, L. B., Univ. of Ky.
6729 Gelder, J. T., Univ. of Kentucky
6730 Haff, F. W., Univ. of Kentucky
6731 Hawkins, R. D., Univ of Ky.
6732 Haynes, T. F., Univ. of Kentucky
6733 Howe, K. P., Univ. of Kentucky
6734 Hughes, M. M., Univ. of Ky.
6735 Ireland, G., Univ. of Kentucky
6736 Jackson, J. T., Jr., Univ. of Ky.
6737 Jefferson, C., Univ. of Kentucky
6738 Lail, W., Jr., Univ. of Kentucky
6739 Mellen, S. B., Univ. of Kentucky
6740 Nunan, T. R., Univ. of Kentucky
6741 O'Bannon, L. S., Univ. of Ky.
6742 Parker, E. E., Univ. of Kentucky
6743 Philpot, N. E., Univ. of Ky.
6744 Puckett, R. D., Univ. of Ky.
6745 Rainey, C. S., Univ. of Ky.
6746 Snodgrass, E. D., Univ. of Ky.
6747 Taylor, R. T., Univ. of Kentucky
6748 Wagner, H. O., Univ. of Kentucky
6749 Walter, E. M., Univ. of Kentucky

Past Section Meetings

Detroit-Ann Arbor.—October 9, 1914, Detroit Engineering Society Rooms. Subject: Railway Work. Paper: "Electrical Distribution System and Method of Handling Cars at the Michigan Central Tunnel, Detroit, Michigan," by C. G. Winslow. Attendance 60.

Lynn.—October 7, 1914, General Electric Works, West Lynn. Address by Mr. Charles Burleigh on "Early Incidents in the Electrical Field." Attendance 168.

Minnesota.—September 19, 1914, Coon Rapids. Visit to power house and dam of Minneapolis Electric Co. at Coon Rapids, followed by illustrated talk by Mr. Walker on construction of dam and power house. Attendance 50.

Panama.—August 23, 1914, New Administration Building. Paper: "Distribution System of Permanent Townsites," by Mr. W. F. Kleene. Attendance 16.

September 19, 1914, Bella Vista, R. de P. Paper: "Mechanical Characteristics of the Loose Wheel Drive as applied to the Operation of Street Cars," by N. K. Ovalla. Attendance 40.

Pittsburgh.—September 22, 1914, Thaw Hall, University of Pittsburgh. Lecture by A.F. Nesbit on "The Electrical Precipitation of Smoke, Dust, etc.", followed by actual demonstration of smoke precipitating and recording devices. Attendance 180.

Pittsfield.—October 7, 1914. Hotel Maplewood. Paper: "Present-Day Tendencies in Electrical Engineering Development," by C. P. Steinmetz. Attendance 167.

Portland.—October 6, 1914. Joint meeting with Portland Section of N. E. L. A. in the form of a dinner at the Automobile Club. Attendance 116.

San Francisco.—August 12, 1914. Election of officers as follows—chairman, C. J. Wilson; secretary, A. G. Jones.

September 25, 1914, Engineers Club of San Francisco. Paper: "Daylight Absorption in Long Distance Radio-telegraphy," by L. F. Fuller. Attendance 31.

Schenectady.—September 8, 1914. Election of officers as follows—chairman, H. M. Hobart; secretary, F. S. Wheeler.

October 6, 1914, Edison Club Hall. Address by Mr. Francis C. Pratt on organization of General Electric Company. Illustrated demonstration lecture by Mr. John B. Taylor on "Color of Light." Attendance 250.

Toledo.—September 16, 1914, Toledo Commerce Club. Report by Mr. Max Neuber on the Annual Convention at Detroit. Attendance 14.

Past Branch Meetings

University of Colorado.—September 23, 1914. Brief talks by Prof. Evans and other members of the faculty.

Georgia School of Technology.—October 9, 1914. Paper: "Development of Protective Apparatus for Telephone Lines Paralleling High-voltage Transmission Systems," by E. P. Peck. Also brief talks by Messrs. A. M. Schoen and Park Dallis. Election of officers as follows—chairman, R. A. Clay; secretary, J. M. Reifsnyder, Jr. Attendance 39.

Iowa State College.—October 14, 1914, Ames, Iowa. Election of officers as follows—chairman, Roscoe Schaffer; secretary, Frank A. Robbins. Attendance 9.

University of Kentucky.—October 14, 1914, Mechanical Hall. Subject: Electric Lighting and Heating. Attendance 32.

Lafayette College.—October 7, 1914, Pardee Hall. Papers: (1) "Types of Underground Conduit Systems," by R. W. Soles; (2) "Plants and System of Pennsylvania Utilities Company," by R. Perry; (3) "The Philadelphia-Paoli Electrification," by R. von Onweger. Attendance 26.

October 14, 1914, Pardee Hall. Papers: (1) "Isolated Plant versus Central Station Supply," by W. H. Powell; (2) "Relation of Load Factor to Cost of Power," by R. McManigal; (3) "How to Improve the Power Factor," by W. B. Killough. Attendance 26.

University of Missouri.—September 28, 1914, Engineering Building. Talk on "Developments in Electrical Engineering Lines" by Dean E. J. McCaustland. Attendance 24.

October 12, 1914, Engineering Building. Talk outlining the production system of a large manufacturing company, by Mr. Kerr Atkinson. Attendance 17.

University of Nebraska.—October 7, 1914, Electrical Building. Brief talks by Prof. Ferguson and Prof. Hollister on Institute and Branch affairs. Attendance 65.

Ohio Northern University.—September 23, 1914, Dukes Memorial. Paper: "High-Voltage Transformers and High-Voltage Measurements," by Prof. McEckron. Brief address by Prof. Thurston on the A. I. E. E. Attendance 30.

October 7, 1914, Dukes Memorial. Papers: "Nitrogen-Filled Mazda," by H. R. Smith; "Lock Control of the Panama Canal," by L. W. Breman. Short talk on "The Gyroscope," by L. L. Daubenspeck. Attendance 20.

Purdue University.—September 22, 1914, Electric Building. Brief addresses by Professors Harding, Ewing and Topping. Attendance 66.

Stanford University.—September 24, 1914, Engineering Building. Papers: "Evolution of the Transformer," by A. Keller; "Campus Light and Power Distribution," by H. I. Scholz. Attendance 14.

University of Washington.—September 17, 1914, Good Roads Building. Address by Prof. C. E. Magnusson. Attendance 72.

October 6, 1914, Good Roads Building. Paper: "The Campus Lighting System of the University of Washington," by F. E. Johnson. Address on "Safety Devices of Submarines," by J. E. Dodds, also "Acceptance Test of a Motor-Generator Set," by Sidney Burbank. Attendance 63.

Worcester Polytechnic Institute.—October 9, 1914, W. P. I. Lecture Hall. Addresses by Messrs. H. L. Cole, D. F. Miner, H. R. Clark and C. D. Haigis, on "Summer Engineering Experiences." Attendance 37.

Personal

Mr. S. E. Hutton was recently appointed engineer for the Public Utilities Commission of Idaho, and is now engaged in investigations bearing on light and power rate cases in northern Idaho.

Mr. Frank B. Dunn, electrical engineer in the Hawthorne Works of the Western Electric Company, has re-

signed his position to take up work in the graduate school of the Ohio State University, Columbus, Ohio.

MR. B. ELSHOFF has recently resigned his position as superintendent of the electrical department of the Canadian Westinghouse Company, Ltd., to become works manager of the Diehl Manufacturing Company, Elizabeth, N. J.

MR. HAMMOND MATHEWS, who has been chief electrician for the Arizona Copper Company and the Arizona and New Mexico Railroad since January, 1911, has accepted a responsible position with the Arizona Power Company and the Prescott Gas and Electric Company, with headquarters at Prescott, Arizona.

MR. WILLIAM R. BOWES, assistant electrical engineer in charge of the electrical division of the Fire Prevention Bureau of the New York Fire Department, was recently elected chairman of the Board of Approval of the Industrial Board. This board passes on all apparatus to be used in connection with interior fire alarm systems installed in factories in New York State.

MR. SERGIUS P. GRACE, for more than ten years chief engineer of the Central District Bell Telephone Company in Pittsburgh, has been appointed assistant engineer of the Public Service Commission of New York State in the investigation and appraisal of the New York Telephone Company. Mr. Grace left Pittsburgh in 1913, shortly after the consolidation of the Central District Company with the Philadelphia Bell Company, and since that time has been in general consultation work in New York.

Obituary

STUART RICHARDSON, City Electrical Engineer to the Wellington, N. Z., Corporation, died on September 11, 1914, after a brief illness. Mr. Richardson was born at Swansea, England, January 9, 1863. After spending some years as a young man in Australia he returned to England, and, taking up the study of electrical engineering, entered the Brush Company's works at Loughborough. After gaining an extensive experience with this firm he was appointed Electrical Engineer to the Corporation of the City of Leicester. In 1899 he left England to take up the position of manager for the New Zealand Electrical Syndicate, which then controlled the electric lighting of the city of Wellington. At the termination of his engagement with that company he entered the service of the Wellington Corporation and in 1905 was appointed to the position of Tramway and Electrical Engineer, which he held until his death. Mr. Richardson was elected an Associate of the A.I.E.E. on January 26, 1906. He was a Member of the (British) Institution of Electrical Engineers.

EMPLOYMENT DEPARTMENT

At the October meeting of the Board of Directors, the Secretary was authorized to establish an employment department, and to publish in the PROCEEDINGS, without charge to members, brief announcements of vacancies, and records of available men, these announcements to be furnished by the members concerned, subject to editorial revision under the direction of the Secretary. It is believed that the establishment of this department in the Institute will be greatly appreciated, and that it will be helpful not only to the members desiring employment, but also to those who have vacancies in their staffs.

Members who desire to avail themselves of this department should forward copy in time to reach the Sec-

retary's office prior to the 15th of the month, for publication in the issue of the following month.

The coöperation of the membership by notifying the Secretary of available positions, is particularly requested.

In accordance with the action of the Board, the following announcements are published. Replies should be addressed to the number indicated in each case, and mailed to Institute headquarters, whence they will be forwarded promptly to the members concerned:

Men Available

101. Sales Engineer. (Degree E.E.) Twelve years experience. Two years power solicitor New York Edison. Ten years with General Electric, testing, construction, engineering, sales. Past five years selling central station apparatus and supplies. Well known in trade New York City and vicinity. Qualified to manage central station.

102. Electrical Engineer (Cornell) with fifteen years general experience, mostly in connection with the development of inventions and the design and manufacture of special machinery. Have also had considerable experience in the installation and repair of submarine cable. Would invest moderate amount in manufacturing proposition including situation.

103. Electrical engineer, graduate of large eastern university, 1910. Experience includes one year as instructor, two years testing and construction work with large telephone company, 16 months testing and installation work with company developing high-grade electrical gas-metering device. Location preferred, middle west. Can refer to present employers.

104. Electrical Engineer, single, graduate Cornell, 1908. With the Western Electric Company 6 years. One year on design of d-c. machinery, and five years on tests, installations and operation of motors, generators, switchboards and storage batteries, with limited selling experience. References furnished.

105. Electrical engineer, graduated from Sheffield Scientific School of Yale in June 1914. Would like position in a manufacturing concern or elsewhere where practical experience may be obtained.

106. Electrical Engineer, technical post-graduate, experienced in designing, constructional, shop and operating work.

107. Electrical engineer open for engagement January first. Fourteen years domestic and foreign experience in the proper design and manufacture of alternating and direct-current generating and utilization apparatus. Control valuable patents. My services will increase your profits. May I tell you how?

108. Electrical Engineer, graduate of Brooklyn Polytechnic Institute, 1905. Since 1905 with well known consulting engineer, engaged in designing, calculating, reporting, and specification writing and experimental work. High-tension transmission lines. Specialized for four years on design, testing and manufacture of porcelain insulators.

109. Graduate of Stevens Institute of Technology, degree of M. E., desires position in commercial department of operating or manufacturing company. Five years experience with large manufacturing companies.

110. Electrical Engineer, graduate of Cornell. Four years experience in General Electric testing, consulting engineering, and a-c. engineering departments Age 28. Can give best of references.

111. Electrical Engineer, technical graduate, is open for engagement. Experience includes two years in testing department of General Electric Company; also two years of electrical, hydraulic and mechanical testing with large eastern power company. Can give best of references.

112. Electrical and mechanical engineer, Fellow A. I. E. E., broad experience in executive capacity, thoroughly conversant in Spanish language and customs by actual residence and travel, desires to represent manufacturer or exporter in South America. At present engaged as general manager of large property. Can leave on short notice.

Library Accessions

The following accessions have been made to the Library of the Institute since the last acknowledgment.

American Electro-Magnetic Telegraph, Its early history as shown by extracts from the records of Alfred Vail, 1914. New York, 1914. (Gift of American Telegraph & Telephone Co.)

Uber die Einwirkung von Strukturänderungen. By Hermann Gewecke. n.p. n.d. (Purchase).

Elektrische Starkstromanlagen. Ed. 2. By Emul Kosack. Berlin, 1914. (Purchase.)

Factory Lighting. By C. E. Clewell. New York 1913. (Purchase).

Kurzes Lehrbuch der Elektrotechnik. Ed 6. By Adolph Thomälen, Berlin, 1914. (Purchase).

National Fire Protection Association. Year Book. 1914. Boston, 1914. (Gift of National Fire Protection Association.)

New York (City) Department of Bridges. Annual report 1913. New York, 1913. (Gift of F. J. H. Kracke.)

New York (State) Public Service Commission. 1st. Dist. Proceedings, volume VIII, 1913. New York, 1913. (Exchange.)

Philadelphia. Department of Public Works. Annual Report of the Director. 1913. Philadelphia, 1913. (Gift of M. L. Cooke.)

GIFT OF ELECTRIC RAILWAY JOURNAL.

Beaumont, W. W. Practical Treatise on the Steam Engine Indicator and Indicator Diagrams. Ed. 2. New York, n.d.

Bramwell, C. C. Construction of a Gasoline Motor Vehicle. New York, n.d.

Doran, J. T. Explanations of Switch and Signal Circuits. New York, 1907.

Elliott, W. H. Block and Interlocking Signals. New York, 1896.

Gillespie, W. M. Treatise on Land-Surveying. Ed. 8. New York, 1883.

Gillette, H. P. Economics of Road Construction. Ed. 2. New York, 1906.

Hawkesworth, John. Graphical Handbook for Reinforced Concrete Design. New York, 1906.

MacCord, C. W., Jr. Slide-valves. New York, 1897.

Moreau, George. Les Moteurs a Explosion. Paris, 1900.

National Brake & Electric Co. National Air Brakes Manual of Installation and Maintenance. Milwaukee, 1907.

Pierce & Richardson. National Electrical Code. Chicago, 1896.

Pullen, W. W. F. Indicator Diagrams. Manchester, 1899.

Reed, H. A. Photography Applied to Surveying. Ed. 2. New York, 1889.

Sabin, A. H. Painting to Prevent Corrosion. New York, 1898.

Sinclair, Angus. Railroad Men's Catechism. New York, 1907.

Zeuner, Gustav. Treatise on Valve-Gears, translated from the German by M. Muller. Ed. 3. London, 1869.

TRADE CATALOGUES.

Bartlett & Snow Co. Cleveland, O. Bull No. 40. Garbage disposal machinery.

——29.—Garbage disposal plants, 1909.

Crown Cork & Seal Co. Baltimore, Md. The Crown cork system. 55 pp.

Delta Star Electric Co. Chicago Ill. Bull No. 8 " Unit Type " high tension wet process bus bar supports. Oct. 1913.

General Electric Co. Schenectady, N. Y. Bull. No. 46390. Thomson direct current test meter, type CB-5. Sept. 1914.

Griscom-Russell Co. New York, N. Y. Bull. No. 703. Rubbish Utilization plant in the City of Pittsburgh, Penn.

——Bull No. 704 (Special) Report of Official Test of Sterling Destructor installed at Halifax, N. S.

Sterling Destructor. 48 pp.

Hammond Engineering Co., Warren, Pa., Sewage disposal. n. d.

Leeds & Northrup Co. Phila. Pa. Catalogue 54. Leeds and Northrup Fault Finder. 12pp.

Metropolitan Electric Mfg. Co. Long Island City, L. I. Catalogue on switchboards and electrical appliances.

Ohio Brass Co. Mansfield, O. O-B Bulletin. Sept.-Oct. 1914.

Philadelphia Electric Co. Philadelphia, Pa. Bulletin, Sept. 1914.

Roto Co. Hartford Conn. Catalogue No. 40.—Types and uses of Roto Cleaners.

——No. 41, 42—Type A. D. &D. W. Boiler tube cleaners.

——No. 43. Cutter heads for boiler tube cleaners.

——No. 44.—Type A. D. Locomotive arch tube cleaner.

——No. 48,—Type P.M. condensed tube cleaners.

Sprague Electric Works. New York, N. Y. Bull No. 48700. Sprague electric monorail cranes.

——Bull No. 48701. Sprague electric dynamometers.

UNITED ENGINEERING SOCIETY

American Library Association. Handbook, 1914. (vol. 8, no. 5, of Bulletin). Chicago, 1914. (Gift of W. P. Cutter.)

A Magyar Mérnökès Epitèsz-Egylet 1914. Budapest, 1914. (Gift of American Society of Hungarian Engineers.)

Motion Picture Trade Directory. August, 1914. New York. 1914. (Gift of Frank Wenneis.)

New International Encyclopaedia. vols. 3-6. New York, 1914 (Purchase.)

New Zealand Patent Office Journal. vol. 1; vol. 2, nos. 1-8, 10-13, 15-25; vol. 3, nos. 1-4 6-14. Wellington, 1912-14. (Gift of Patent Office.)

Oil Paint & Drug Reporter. Green Book for Buyers, January 1914 edition. New York, 1914. (Gift of Oil, Paint and Drug Reporter.)

Passenger Car Ventilation System of the Pennsylvania Railroad Company. By Chas. B. Dudley. Altoona, 1914. (Gift of Pennsylvania Railroad Co.)

Patents. By Chas. L. Clarke. (Reprinted from " General Electric Review.") n.p. n.d. (Gift of author.).

Publishers' Trade List Annual, 1914. New 1914. New York, 1914. (Purchase)

Testing of Wood Pulp. A Practical Handbook for the Pulp and Paper Trades. By Sindall and Bacon. London, 1912. (Purchase.)

Who's Who in America. vol. VIII, 1914-1915. Chicago, 1914. (Purchase.)

OFFICERS AND BOARD OF DIRECTORS, 1914-1915

PRESIDENT.
(Term expires July 31, 1915.)
PAUL M. LINCOLN.

JUNIOR PAST-PRESIDENTS.

(Term expires July 31, 1915.)	(Term expires July 31, 1916.)
RALPH D. MERSHON.	C. O. MAILLOUX.

VICE-PRESIDENTS.

(Term expires July 31, 1915.)	(Term expires July 31, 1916.)
J. A. LIGHTHIPE.	F. S. HUNTING.
H. H. BARNES JR.	N. W. STORER.
CHARLES E. SCRIBNER.	FARLEY OSGOOD.

MANAGERS.

(Term expires July 31, 1915.)	(Term expires July 31, 1916.)	(Term expires July 31, 1917.)
COMFORT A. ADAMS.	H. A. LARDNER.	FREDERICK BEDELL.
J. FRANKLIN STEVENS.	B. A. BEHREND.	BANCROFT GHERARDI.
WILLIAM B. JACKSON.	PETER JUNKERSFELD	A. S. McALLISTER.
WILLIAM McCLELLAN	L. T ROBINSON.	JOHN H. FINNEY.

TREASURER.		SECRETARY.
GEORGE A. HAMILTON.	(Term expires July 31 1915.)	F. L. HUTCHINSON.

HONORARY SECRETARY.
RALPH W. POPE,
33 West 39th Street New York

LIBRARIAN.
W. P. CUTTER,
29 West 39th Street, New York.

GENERAL COUNSEL.
PARKER and AARON,
.2 Broadway, New York.

PAST-PRESIDENTS.—1884-1914.

*NORVIN GREEN, 1884-5-6.
*FRANKLIN L. POPE, 1886-7.
T. COMMERFORD MARTIN, 1887-8.
EDWARD WESTON, 1888-9.
ELIHU THOMSON, 1889-90.
*WILLIAM A. ANTHONY, 1890-91.
ALEXANDER GRAHAM BELL, 1891-2.
FRANK JULIAN SPRAGUE, 1892-3.
*EDWIN J. HOUSTON, 1893-4-5.
LOUIS DUNCAN, 1895-6-7.
FRANCIS BACON CROCKER, 1897-8.
A. E. KENNELLY, 1898-1900.
CARL HERING, 1900-1.
CHARLES P. STEINMETZ, 1901-2.
CHARLES F. SCOTT, 1902-3.
BION J. ARNOLD, 1903-4.
JOHN W. LIEB Jr., 1904-5.
SCHUYLER SKAATS WHEELER, 1905-6.
SAMUEL SHELDON, 1906-7.
HENRY G. STOTT, 1907-8.
LOUIS A. FERGUSON, 1908-09.
LEWIS B. STILLWELL, 1909-10.
DUGALD C. JACKSON, 1910-11.
GANO DUNN, 1911-12.
RALPH D. MERSHON, 1912-13.
C. O. MAILLOUX, 1913-14.

*Deceased.

STANDING COMMITTEES

Revised to Nov. 1, 1914

EXECUTIVE COMMITTEE.

P. M. Lincoln, Chairman,
W. E. and M. Company, East Pittsburgh, Pa.
C. A. Adams, G. A. Hamilton,
H. H. Barnes, Jr., William McClellan,
B. A. Behrend, N. W. Storer.

FINANCE COMMITTEE

J. F. Stevens, Chairman,
1326 Chestnut St., Philadelphia, Pa.
H. H. Barnes, Jr. B. Gherardi.

LIBRARY COMMITTEE.

Samuel Sheldon, Chairman,
198½ Schermerhorn St., Brooklyn, N. Y.
B. Gherardi, Harold Pender,
F. L. Hutchinson, W. I. Slichter.

MEETINGS AND PAPERS COMMITTEE.

L. T. Robinson, Chairman,
General Electric Company, Schenectady, N. Y.
L. W. Chubb, H. H. Norris,
S. M. Kintner, C. P. Steinmetz,
and the chairmen of all technical committees.

EDITING COMMITTEE.

H. H. Norris, Chairman,
239 West 39th St., New York.
M. G. Lloyd, W. S. Rugg,
A. S. McAllister, W. I. Slichter.

BOARD OF EXAMINERS.

Maurice Coster, Chairman,
165 Broadway, New York.
Philander Betts, A. S. McAllister,
Henry Floy, John B. Taylor.

SECTIONS COMMITTEE.

H. A. Hornor, Chairman,
Hamilton Court, 39th and Chestnut Streets, Philadelphia, Pa.
Frederick Bedell, W. A. Hall,
H. W. Flashman, F. D. Nims.
Charles F. Scott,
and the chairmen of all Institute Sections.

STANDARDS COMMITTEE.

A. E. Kennelly, Chairman,
Harvard University, Cambridge, Mass
C. A. Adams, Secretary,
Harvard University, Cambridge, Mass.
James Burke, W. H. Powell,
W. A. Del Mar, Charles Robbins,
H. W. Fisher, L. T. Robinson,
H. M. Hobart, E. B. Rosa,
F. B. Jewett, C. E. Skinner,
P. Junkersfeld, J. M. Smith,
G. L. Knight, H. G. Stott,
W. L. Merrill, P. H. Thomas.

CODE COMMITTEE.

Farley Osgood, Chairman,
763 Broad Street, Newark, N. J.
J. C. Forsyth, A. M. Schoen,
H. B. Gear, George F. Sever,
Kempster B. Miller, H. O. Lacount,
H. N. Muller, C. E. Skinner,
H. R. Sargent.

LAW COMMITTEE.

G. H. Stockbridge, Chairman,
165 Broadway, New York.
Charles L. Clarke, Paul Spencer,
C. E. Scribner, Charles A. Terry.

SPECIAL COMMITTEES

Revised to Nov 1, 1914.

POWER STATIONS.

H. G. Stott, Chairman,
600 West 59th Street, New York.
W. S. Gorsuch, C. S. MacCalla,
J. H. Hanna, R. J. S. Piggott,
C. A. Hobein, E. F. Scattergood.
A. S. Loizeaux, Paul Spencer,
C. F. Uebelacker.

TRANSMISSION COMMITTEE.

P. H. Thomas, Chairman,
2 Rector St., New York.
E. J. Berg, V. D. Moody,
P. M. Downing, F. D. Nims,
A. R. Fairchild, F. W. Peek, Jr.,
F. A. Gaby, Harold Pender,
L. E. Imlay, K. C. Randall,
L. R. Lee, C. S. Ruffner,
G. H. Lukes, F. D. Sampson,
Ralph D. Mershon, P. W. Sothman,
W. E. Mitchell, C. E. Waddell,
J. E. Woodbridge.

RAILWAY COMMITTEE.

D. C. Jackson, Chairman,
248 Boylston Street, Boston, Mass.
A. H. Armstrong, E. B. Katte,
A. H. Babcock, Paul Lebenbaum,
E. J. Blair, W. S. Murray,
H. M. Brinckerhoff, Clarence Renshaw,
E. P. Burch, A. S. Richey,
H. M. Hobart, F. J. Sprague,
N. W. Storer.

PROTECTIVE APPARATUS.

[Not yet appointed.]

ELECTRIC LIGHTING COMMITTEE.

Clayton H. Sharp, Chairman,
556 East 80th St., N. Y.
J. W. Cowles, H. W. Peck,
E. P. Hyde, S. G. Rhodes,
P. Junkersfeld, E. B. Rosa,
A. S. Loizeaux, G. H Stickney,
T. S. Perkins, C. W. Stone.

INDUSTRIAL POWER COMMITTEE.

D. B. Rushmore, Chairman,
General Electric Company Schenectady, N. Y.
A. C. Eastwood, J. P. Mallett,
Walter A. Hall, E. H. Martindale,
J. M. Hipple, W. L. Merrill,
G. H. Jones, J. A. Osborn,
C. D. Knight, A. G. Pierce,
J. C. Lincoln, H. A. Pratt.

TELEGRAPHY AND TELEPHONY COMMITTEE.

C. E. Scribner, Chairman,
463 West Street, New York.
Minor M. Davis, K. B. Miller,
C. L. Fortescue, H. Mouradian,
H. M. Friendly, W O. Pennell.
A. H. Griswold, F. L. Rhodes,
F. B. Jewett, John B. Taylor,
S. M. Kintner, J. L. Wayne,
William Maver, Jr. G. M. Yorke.

COMMITTEE ON USE OF ELECTRICITY IN MINES.

Wilfred Sykes, Chairman,
Box 242, East Liberty, Pa.

F. E. Alexander, M. H. Gerry, Jr.
C. W. Beers, Charles Legrand,
W. W. Briggs, K. A. Pauly,
Graham Bright, G. B. Rosenblatt,
B. T. Viall.

COMMITTEE ON USE OF ELECTRICITY IN MARINE WORK

C. S. McDowell, Chairman.
Navy Yard, New York.

Maxwell W. Day, H. A. Hornor,
W. L. R. Emmet, O. P. Loomis,
F. C. Hanker, D. M. Mahood,
H. L. Hibbard, Elmer A. Sperry,
Guy Hill, G. A. Pierce, Jr.,
F. W. Wood.

IRON AND STEEL INDUSTRY.

[Not yet appointed.]

ELECTROCHEMICAL COMMITTEE.

A. F. Ganz, Chairman.
Stevens Institute, Hoboken, N. J.

Lawrence Addicks, E. F. Price,
C. F. Burgess, C. G. Schluederberg,
Carl Hering, L. L. Summers.
W. R. Whitney,

ELECTROPHYSICS COMMITTEE.

J. B. Whitehead, Chairman,
Johns Hopkins University, Baltimore, Md

Frederick Bedell, E. L. Nichols,
H. L. Blackwell, E. B. Rosa,
L. W. Chubb, H. J. Ryan,
W. S. Franklin, H. Clyde Snook.

COMMITTEE ON RECORDS AND APPRAISALS OF PROPERTIES.

William B. Jackson, Chairman,
111 W. Monroe Street, Chicago, Ill.

Philander Betts, W. J. Norton,
William H. Blood, Jr., C. L. Pillsbury,
Fred A. Bryan, H. Spoehrer,
C. L. Cory, W. G. Vincent,
Clifton W. Wilder.

EDUCATIONAL COMMITTEE.

V. Karapetoff, Chairman.
Cornell University, Ithaca, N. Y.

B. J. Berg, A. S. Langsdorf,
F. L. Bishop, C. E. Magnusson,
C. R. Dooley, Charles F. Scott,
G. A. Hoadley, P. B. Woodworth.

PUBLIC POLICY COMMITTEE.

Calvert Townley, Chairman,
165 Broadway, New York.

H. W. Buck, H. A. Lardner,
Fredk. Darlington, William McClellan,
Gano Dunn, E. W. Rice, Jr.,
John H. Finney, L. B. Stillwell,
H. G. Stott.

PATENT COMMITTEE.

Ralph D. Mershon, Chairman,
80 Maiden Lane, New York.

Bion J. Arnold, O. S. Schairer,
C. S. Bradley, C. E. Scribner,
Val. A. Fynn, F. J. Sprague,
John F. Kelly, C. A. Terry,
H. Ward Leonard, E. S. Northrup.

MEMBERSHIP COMMITTEE.

H. D. James, Chairman,
W. E. and M. Company, East Pittsburgh, Pa.

Markham Cheever, A. G. Jones,
E. L. Doty, S. C. Lindsay,
Walter A. Hall, Herbert S. Sands,
Max Hebgen, M. S. Sloan,
H. A. Hornor, W. S. Turner,
P. B. Woodworth.

HISTORICAL MUSEUM COMMITTEE.

T. C. Martin, Chairman,
29 West 39th Street, New York.

John J. Carty, E. W. Rice, Jr.,
Charles L. Clarke, Charles F. Scott,
Louis Duncan, Frank J. Sprague.

U. S. NATIONAL COMMITTEE OF THE INTERNATIONAL ELECTROTECHNICAL COMMISSION

C. O. Mailloux, President,
20 Nassau Street, New York

F. B. Crocker, Vice-Pres., A. E. Kennelly, Sec.,
Harvard University, Cambridge, Mass.

C. A. Adams, E. B. Rosa,
B. A. Behrend, C. F. Scott,
James Burke, C. H. Sharp,
Louis Bell, C. E. Skinner,
J. J. Carty, Samuel Sheldon,
Gano Dunn, Charles P. Steinmetz,
H. M. Hobart, H. G. Stott,
John W. Lieb, Elihu Thomson.
Philip Torchio.

INTERNATIONAL ELECTRICAL CONGRESS, SAN FRANCISCO, 1915.

EXECUTIVE COMMITTEE OF COMMITTEE ON ORGANIZATION.

Charles P. Steinmetz, Honorary President of Congress,
E. B. Rosa, Honorary Secretary of Congress,
H. G. Stott, Chairman,
600 West 59th Street, New York,
John W. Lieb, Vice-Chairman,
C. O. Mailloux, Chairman, Sub-Committee on International Relations,
A. E. Kennelly, Chairman, Sub-Committee on Program,
Henry A. Lardner, Chairman, Sub-Committee on Pacific Coast Relations,
H. H. Barnes, Jr., Chairman, Sub-Committee on Transportation,
George F. Sever, Chairman, Sub-Committee on Entertainment,
Preston S. Millar, Secretary-Treasurer and Chairman, Sub-Committee on Publicity. 556 East 80th Street, New York,
F. L. Hutchinson, Secretary, A. I. E. E. [*Ex Officio*].

COMMITTEE ON RELATIONS OF CONSULTING ENGINEERS.

L. B. Stillwell, Chairman,
100 Broadway, New York.

H. W. Buck, F. R. Ford,
Gano Dunn, F. N. Waterman.

COMMITTEE ON CODE OF PRINCIPLES OF PROFESSIONAL CONDUCT.

George F. Sever, Chairman,
13 Park Row, New York.

H. W. Buck, John F. Kelly,
Gano Dunn, Schuyler Skaats Wheeler.

EDISON MEDAL COMMITTEE.

Appointed by President for terms of five years.

Term expires July 31, 1919.
Charles F. Brush, William Stanley,
N. W. Storer.

Term expires July 31, 1918.
H. W. Buck, J. Franklin Stevens,
F. A. Scheffler.

Term expires July 31, 1917.
A. E. Kennelly, H. Ward Leonard,
Robert T. Lozier,

Term expires July 31, 1916
Frank J. Sprague
Schuyler Skaats Wheeler, Chairman,
Ampere, N. J.
W. D. Weaver.

Term expires July 31, 1915.
Elihu Thomson, J. W. Lieb, Jr.,
E. L. Nichols.

Elected by the Board of Directors from its own membership for terms of two years.

Term expires July 31, 1915.
H. H. Barnes, Jr., William McClellan,
A. S. McAllister.

Term expires July 31, 1916.
C. E. Scribner, C. O. Mailloux,
L. T. Robinson.

Ex-Officio.
P. M. Lincoln, President.
George A. Hamilton, Treasurer.
F. L. Hutchinson, Secretary.

INSTITUTE REPRESENTATIVES

ON BOARD OF AWARD, JOHN FRITZ MEDAL

Dugald C. Jackson, Ralph D. Mershon,
Gano Dunn, C. O. Mailloux.

ON BOARD OF TRUSTEES, UNITED ENGINEERING SOCIETY.

Gano Dunn. Charles E. Scribner.
H. H. Barnes, Jr.

ON LIBRARY BOARD OF UNITED ENGINEERING SOCIETY.

Samuel Sheldon, Harold Pender,
B. Gherardi, W. I. Slichter,
F. L. Hutchinson.

ON ELECTRICAL COMMITTEE OF NATIONAL FIRE PROTECTION ASSOCIATION.

The chairman of the Institute's Code Committee,
Farley Osgood.

ON ADVISORY BOARD OF AMERICAN YEAR-BOOK.

Edward Caldwell.

ON ADVISORY BOARD, NATIONAL CONSERVATION CONGRESS.

Calvert Townley.

ON COUNCIL OF AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

W. S. Franklin. G. W. Pierce.

ON CONFERENCE COMMITTEE OF NATIONAL ENGINEERING SOCIETIES.

Calvert Townley, William McClellan.

ON JOINT COMMITTEE ON ENGINEERING EDUCATION.

Charles F. Scott, Samuel Sheldon.

ON AMERICAN ELECTRIC RAILWAY ASSOCIATION'S COMMITTEE ON JOINT USE OF POLES.

Farley Osgood, F. B. H. Paine,
Percy H. Thomas.

ON NATIONAL JOINT COMMITTEE ON OVERHEAD LINE CONSTRUCTION.

Farley Osgood, F. B. H. Paine,
Percy H. Thomas.

ON NATIONAL COMMITTEE ON ELECTROLYSIS.

Bion J. Arnold, F. N. Waterman,
Paul Winsor.

ON BOARD OF MANAGERS, PANAMA-PACIFIC INTERNATIONAL ENGINEERING CONGRESS, 1915.

A. M. Hunt. J. G. DeRemer.
And the President and Secretary of the Institute.

ON JOINT COMMITTEE ON REGISTRATION OF ENGINEERS

William McClellan, S. D. Sprong,

LOCAL HONORARY SECRETARIES.

Guido Semenza. N. 10, Via S. Radegonda, Milan, Italy.
Robert Julian Scott. Christ Church, New Zealand.
T. P. Strickland, N. S. W. Government Railways, Sydney, N. S. W.
L. A. Herdt, McGill Univ., Montreal Que.
Henry Graftio, Petrograd, Russia.
Richard O. Heinrich, Genest-str. 5 Schoeneberg, Berlin, Germany.
A. S. Garfield, 67 Avenue de Malakoff, Paris, France.

ON U. S. NATIONAL COMMITTEE OF INTERNATIONAL ILLUMINATION COMMITTEE

A. E. Kennelly, C. O. Mailloux,
Clayton H. Sharp.

LIST OF SECTIONS

Atlanta, chairman, A. M. Schoen; secretary, H. M. Keys, Southern Bell Tel. & Tel. Co., Atlanta, Ga.

Baltimore, chairman, J. B. Whitehead; secretary, L. M. Potts, Industrial Building, Baltimore, Md.

Boston, chairman, George W. Palmer, Jr.; secretary, Ira M. Cushing, 84 State St., Boston, Mass.

Chicago, chairman, E. W. Allen; secretary, W. J. Norton, 112 W. Adams Street, Chicago, Ill.

Cleveland, chairman, Howard Dingle; secretary, R. E. Scovel, 1663 East 86th Street, Cleveland, Ohio.

Detroit-Ann Arbor, chairman, H. H. Norton; secretary, Ray K. Holland, Cornwell Building, Ann Arbor, Mich.

Fort Wayne, chairman, L. D. Nordstrum; secretary, J. J. A. Snook, 927 Organ Avenue, Ft. Wayne, Ind.

Indianapolis-Lafayette, chairman, O. S. More; secretary, G. B. Schley, 908 Hume-Mansur Building, Indianapolis, Ind.

Ithaca, chairman, E. L. Nichols; secretary, W. G. Catlin, Cornell University, Ithaca, N. Y.

Los Angeles, chairman, C. G. Pyle; secretary, Edward Woodbury, Pacific Lt. & Pr. Company, Los Angeles, Cal.

Lynn, chairman, W. H. Pratt; secretary, F. S. Hall, General Electric Co., Lynn, Mass.

Madison, chairman, J. W. Shuster; secretary, F. A. Kartak, Univ. of Wisconsin, Madison, Wis.

Mexico,

Milwaukee, chairman, L. L. Tatum; secretary, W. J. Richards, National Brake and Electric Co. Milwaukee, Wis.

Minnesota, chairman, Leo H. Cooper; secretary, Emil Anderson, 1236 Plymouth Bldg., Minneapolis, Minn.

Panama, chairman, Hartley Rowe; secretary, Clayton J. Embree, Balboa Heights, C.Z.

Philadelphia, chairman, H. F. Sanville; secretary, W. F. James, 1115 North American Bldg., Philadelphia, Pa.

Pittsburgh, chairman, J. W. Welsh; secretary, Charles R. Riker, Electric Journal, Pittsburgh, Pa.

Pittsfield, chairman, W. W. Lewis; secretary, M. E. Tressler, General Electric Company, Pittsfield, Mass.

Portland, Ore., chairman, R. F. Monges; secretary, Paul Lebenbaum, 45 Union Depot, Portland, Ore.

St. Louis, chairman, S. N. Clarkson: secretary, A. McR. Harrelson, 5929 DeGiverville Avenue; St. Louis, Mo.

San Francisco, chairman, C. J. Wilson; secretary, A. G. Jones, 819 Rialto Building, San Francisco, Cal.

Schenectady, chairman, H. M. Hobart; secretary, F. S. Wheeler, Gen. Elec. Co., Schenectady, N. Y.

Seattle, chairman, S. C. Lindsay; secretary, E. A. Loew, University of Washington, Seattle, Wash.

Spokane, chairman, J. W. Hungate; secretary, L. N. Rice, Parsons Hotel, Spokane, Wash.

Toledo, chairman, George E. Kirk; secretary, Max Neuber, Cohen, Friedlander & Martin, Toledo, O.

Toronto, chairman, D. H. McDougall, secretary, H. T. Case, Continental Life Bldg., Toronto, Ont.

Urbana, chairman, I. W. Fisk; secretary, P. S. Biegler, University of Illinois, Urbana, Ill.

Vancouver, chairman, E. M. Breed; secretary, L. G. Robinson, 1003 Holden Building, Vancouver, B. C.

Washington, D.C., chairman, C. B. Mirick; secretary, C. A. Peterson, 1223 Vermont Ave., N. W Washington, D. C.

LIST OF BRANCHES

Agricultural and Mechanical College of Texas, chairman, J. F. Nash; secretary, A. Dickie A & M. College, College Station, Tex.

Arkansas, Univ. of., chairman, S. S. McGill; secretary, M. B. Roys, Univ. of Arkansas, Fayetteville Ark.

Armour Institute, chairman, Walter L. Burroughs; secretary, Chester F. Wright, 3341 Michigan Boulevard, Chicago, Ill.

Bucknell University, chairman, F. O. Schnure; secretary, J. M. Hillman, Bucknell University, Lewisburg, Pa.

California, Univ. of., chairman, L. R. Chilcote; secretary, E. S. Meddaugh, 2521 Channing Way Berkeley, Cal.

Cincinnati, Univ. of., chairman, M. L. Harned; secretary, A. C. Perry, University of Cincinnati, Cincinnati, O.

Clemsom Agricultural College, chairman, F. J. Jervey; secretary, F. H. McDonald, Clemson College, S. C.

Colorado State Agricultural College, chairman, L. M. Klinefelter; secretary, R. K. Havighorst, Colorado State Agricultural College, Fort Collins, Colo.

Colorado, Univ. of., chairman, Philip S. Borden; secretary, Charles S. Miller, University of Colorado, Boulder, Colo.

Georgia School of Technology, chairman, R. A. Clay; secretary, J. M. Reifsnyder, Jr., Georgia School of Technology, Atlanta, Ga.

Highland Park College, chairman, Clyde Prussman; secretary, Ralph R. Chatterton, Highland Park College, Des Moines, Iowa.

Idaho, University of.,

Iowa State College, chairman, Roscoe Schaffer; secretary, F. A. Robbins, Iowa State College, Ames, Iowa.

Iowa, Univ. of., chairman, secretary, A. H. Ford, University of Iowa, Iowa City, Ia.

Kansas State Agr. Col., chairman, L. O'Brien; secretary, W. C. Lane, Kansas State Agric. Col., Manhattan, Kan.

Kansas, Univ. of., chairman, H. C. Hansen; secretary, L. M. Bocker, Univ. of Kansas, Lawrence, Kansas.

Kentucky, State Univ. of., chairman, Harry Y. Barker; secretary, G. F. Campbell, 345 South Limestone Street, Lexington, Ky.

Lafayette College, chairman, R. McManigal; secretary, W. J. English, Jr., Lafayette College, Easton, Pa.

Lehigh University, chairman, N. F. Matheson; secretary, F. C. Brockman, Lehigh University, S. Bethlehem, Pa.

Lewis Institute, chairman, A. H. Fensholt; secretary, Fred A. Rogers, Lewis Institute, Chicago, Ill.

Maine, Univ. of., chairman, C. M. Kelly; secretary, E. L. Getchell, University of Maine, Orono, Maine.

Michigan, Univ. of., chairman, H. A. Enos; secretary, H. W. Stubbs, University of Michigan, Ann Arbor, Mich.

Missouri, Univ. of., chairman, E. W. Kellogg; secretary, K. Atkinson, University of Missouri, Columbia, Mo.

Montana State Col., chairman, John M. Fiske; secretary, J. A. Thaler, Montana State College, Bozeman, Mont.

Nebraska, Univ. of., chairman, Olin J. Ferguson; secretary, V. L. Hollister, Station A, Lincoln, Nebraska.

New Hampshire Col.,

North Carolina Col. of Agr. and Mech. Arts, chairman, A. C. Fluck, secretary, R. Crowder, West Raleigh, N. C.

Ohio Northern Univ., chairman, R. E. Lowe; secretary, W. F. Schott, 426 South Union Street, Ada, Ohio.

Ohio State Univ., chairman, Leslie J. Harter; secretary, Robert C. Schott, 38 14th Avenue, Columbus, Ohio.

Oklahoma Agricultural and Mech. Col., chairman, A. P. Little; secretary, Quentin Graham, 118 Husband St., Stillwater, Okla.

Oklahoma, Univ. of., chairman, R. D. Evans; secretary, L. J. Hibbard, Univ. of Oklahoma, Norman, Okla.

Oregon Agr. Col., chairman, W. R. Grasle; secretary, Winfield Eckley, Oregon Agric. Col., Corvallis, Ore.

Penn State College, chairman, A. D. Shultz; secretary, A. T. McNeile, State College, Pa.

Pittsburgh, University of., chairman, B. E. O'Hagan; secretary, George Hickman, University of Pittsburgh, Pittsburgh, Pa.

Purdue Univ., chairman, L. W. Spray; secretary, R. E. Tafel, Purdue University, Lafayette, Ind.

Rensselaer Poly. Inst., chairman, W. J. Williams; secretary, W. E. Coover, 74 Eagle Street. Troy, N. Y.

Rose Polytechnic Inst., chairman, Charles F. Harris; secretary, Claude A. Lyon, 1331 Liberty Avenue, Terre Haute, Ind.

Rhode Island State Col., chairman, W. C. Miller; secretary, P. M. Randall, Jr., Rhode Island State College, Kingston, R. I.

Stanford Univ., chairman, G. L. Beaver; secretary, H. J. Scholz, Stanford University, Cal.

Syracuse Univ., chairman, W. P. Graham; secretary, R. A. Porter, Syracuse University, Syracuse, N. Y.

Texas, Univ. of., chairman, Joseph W. Ramsey; secretary, J. A. Correll, University of Texas, Austin, Tex.

Throop College of Technology, chairman, W. L. Newton; secretary, A. W. Wells, Throop Poly. Institute, Pasadena, Cal.

Virginia, Univ. of., chairman, Walter S. Rodman; secretary, H. Anderson, Jr., 1022 West Main St., Charlottesville, Va.

Wash., State Col. of., chairman, M. K. Akers; secretary, H. V. Carpenter, State Coll. of Wash., Pullman, Wash.

Washington Univ., chairman, C. C. Hardy, secretary, Charles P. Seeger, Washington University, St. Louis, Mo.

Washington, Univ. of., chairman, H. W. McRobbie; secretary, B. B. Bessesen, Univ. of Washington, Seattle, Wash.

Worcester Poly. Inst., chairman, Frank Aiken; secretary, A. B. R. Prouty, Worcester Poly. Inst., Worcester, Mass.

Yale University, chairman, F. M. Doolittle; secretary, K. Lessey, 106 Van. Sheff., New Haven, Conn.

SECTION II

PROCEEDINGS

of the

American Institute

of

Electrical Engineers

Papers, Discussions and Reports

CONTENTS OF SECTION II

PROCEEDINGS

OF THE

American Institute

OF

Electrical Engineers.

Published monthly by the A. I. E. E.. at 33 W. 39th St., New York, under the supervision of

THE EDITING COMMITTEE

GEORGE R. METCALFE, Editor

Subscription. $10.00 per year for all countries to which the bulk rate of postage applies,
All other countries $12.00 per year.
Single copy $1.00
Subscriptions must begin with January issue.

Changes of advertising copy should reach this office by the 15th of the month, for the issue of the following month.

Vol. XXXIII **December, 1914** No. 12

Institute Meeting in New York, December 11, 1914

The 302nd meeting of the American Institute of Electrical Engineers will be held on the fifth floor of the Engineering Societies Building, 33 West 39th Street, New York, on Friday, December 11th, at 8:15 p.m. The meeting rooms will be opened an hour in advance of the meeting for informal conference of members and guests.

Two papers will be presented at the meeting, as follows:

Insulator Depreciation and Effect on Operation, by A. O. Austin, and *Effect of Altitude on the Spark-over Voltages of Bushings, Leads and Insulators*, by F. W. Peek, Jr. Both of these papers are published elsewhere in this issue of the PROCEEDINGS, and reprints may be obtained on application to the Secretary.

At the close of the technical session a smoker will be held and light refreshments served in the adjoining room on the fifth floor.

Nominations for Institute Officers for 1915-16

As provided in Section 18 of the Institute by-laws, candidates may now be proposed for nomination for the offices to be filled at the next annual election in May, 1915, by the petition or by the separate endorsement in writing, of not less than fifty members. The petitions or separate endorsements must be in the hands of the Secretary not later than January 25, 1915. For the convenience of members, a form of petition has been prepared by the Secretary, and copies of it may be obtained upon application to Institute headquarters. Endorsements may, however, be made by letter if the form is not available.

The officers to be elected are: a President and a Treasurer, for the term of one year each, three Vice-Presidents for the term of two years each, and four Managers for the term of three years each.

For the information of members, the full text of Section 18 of the by-laws, governing the proposal of candidates for nomination, is printed below:

"SEC. 18. In addition to the names of the incumbents of office, the Secretary shall publish on 'the form showing offices to be filled at the ensuing annual election in May,' provided for in Article VI, Section 30, of the Constitution, the names, as candidates for nomination, of such members of the Institute as have been proposed for nomination for a particular office by the petition or by the separate endorsement of not less than fifty members, received by the Secretary of the Institute in writing by January 25 of each year.

"The names of such candidates for nomination shall be grouped alphabetically under the name of the office for which each is proposed, and this by-law shall be reprinted prominently in the January issue of each year's PROCEEDINGS, and shall be reproduced on the form above referred to."

Benefits of Institute Membership

The American Institute of Electrical Engineers was the first of the national engineering societies to develop Section work as one of its activities. This department of our work has developed

greatly in the last few years and offers unusual advantages to the membership at large.

The following letter received from Mr. A. M. Dudley, who was chairman of the Pittsburgh Section last year, brings out the advantages of our Section and Branch work. These points can be readily emphasized in presenting the work of the Institute to prospective members.

H. D. JAMES
Chairman, Membership Committee.

November 23, 1914

Mr. H. D. James,
Chairman, Membership Committee.

In reply to your inquiry as to what I consider the special benefits accruing to Institute members through the existence of local Sections and their contact with these Sections, I would suggest the following points:

1st: Opportunity is offered for regular attendance at least once a month, at a meeting conducted by the Institute. This is beneficial in at least two ways. Since it is a regular schedule the dates can be arranged in the personal calendar. Also the habit is formed by regularly devoting an evening to the consideration of engineering problems and results aside from the personal work.

2nd: The papers which are presented at the Section meetings, in general, are of keen local interest throughout the entire year, as compared with the New York papers which must, of necessity, embrace all fields with a limited number of papers.

3rd: The local Section meetings allow a thoroughly informal interchange of ideas. It is a well-known fact that many men will stand up among their local friends and colloquially present ideas of the greatest interest in the art, which they would be embarrassed in presenting before what they considered a learned, technical body, which by its inherent makeup must needs be critical. This covers the point also that numbers of short papers are prepared and presented locally with good results, whose authors are too modest to make them sufficiently formal for the Institute records, or which were not considered of more than local interest.

4th: The Section meetings widen local acquaintance. It is not necessary to mention all the benefits from this but it may be suggested that it is of benefit socially, professionally and commercially.

5th: The Section meetings promote acquaintance with allied branches of engineering. This comes about through co-operation with local Sections of allied societies and with other local societies in the way of joint meetings. This is broadening and tends to correct the present-day tendency towards too cramped specialization.

There are probably many other benefits from the local Section which will suggest themselves to you, and if these are not convincing, I can assure you that any member of the Institute who will concern himself actively with the conduct of his local Section will, after one year, become an enthusiastic booster who can supply you with ten or a dozen more benefits which he has practically demonstrated.

Yours sincerely,

A. M. DUDLEY,
Past Chairman, Pittsburgh Section

Electrical Committee, National Fire Protection Association

The biennial meeting of the Electrical Committee of the National Fire Protection Association will be held in March, 1915, in New York City, the day and place of the meeting to be announced later. As usual, the provisions of the National Electrical Code as they now exist will be considered, together with reports of all sub-committees.

Suggestions for amendments to the Code, in order to be included in the Bulletin, must be specific, and where a change is desired in a rule or section of a rule, definite wording for such change must be given, together with the reasons why the change is recommended, and these suggestions, together with all committee reports, must be in the hands of the secretary of the committee, Mr. Ralph Sweetland, 141 Milk St., Boston, Mass., *not later than January 15th*, 1915.

As heretofore, the meeting will be open to all interested, and such persons will not only be welcome but are urged to be present and give the Committee the advantage of their experience and advice.

Directors' Meeting, New York, November 13, 1914

The regular monthly meeting of the Board of Directors of the Institute was held in New York on Friday, November 13, at 3:30 p.m.

There were present: President Paul M. Lincoln, Pittsburgh, Pa., Past-President C. O. Mailloux, New York; Vice-Presidents H. H. Barnes, Jr., New York, N. W. Storer, Pittsburgh, Pa., Farley Osgood, Newark, N. J.; Managers C. A. Adams, Cambridge, Mass., J. Franklin Stevens, Philadelphia, Pa., William McClellan, New York, L. T. Robinson, Schenectady, N. Y., Bancroft Gherardi, New York, John H. Finney, Washington, D. C.; Treasurer George A. Hamilton, Elizabeth, N. J., and Secretary F. L. Hutchinson, New York.

The action of the Finance Committee in approving monthly bills amounting to $11,746.18 was ratified.

Upon the petition of Prof. W. E. Dickinson, of the West Virginia University, Morgantown, W. Va., and with the approval of the chairman of the Sections Committee, authority was granted for the organization of a Branch at that university.

In accordance with action taken by the Section Delegates in conference at the Detroit Convention last June, Section 55 of the Institute by-laws, relating to the term of office of the Section chairmen and secretaries, was amended so as to permit the term of office to begin either on January 1 or August 1. The former by-law provided that the term of office should coincide with that of the officers of the Institute, beginning on August 1, and, accordingly, the majority of the Sections hold their annual meetings in May or June, at the close of the active season, and begin their administrative year in August. Some of the Sections, however, consider it desirable to begin their administrative year on January 1, and the change was made for the benefit of these Sections.

Upon the recommendation of the Board of Examiners, 29 applicants were elected to the grade of Associate, and 108 students were ordered enrolled.

A considerable amount of other business was transacted by the Board, reference to which will be found under appropriate headings in this and future issues of the PROCEEDINGS.

Past Institute Meetings

New York.—The 301st meeting of the Institute was held Friday, November 13, 1914, in the auditorium of the Engineering Societies Building, beginning at 8:25 p.m. President Paul M. Lincoln presided.

Mr. E. C. Woodruff presented his paper, entitled *Graphic Method for Speed-Time and Distance-Time Curves.* This was discussed by Messrs. Selby Haar, C. O. Mailloux, Nicholas W. Akimoff, F. Castiglioni, F. E. Wynne, N. W. Storer, Edward E. Kimball, and E. C. Woodruff.

The paper by Mr. Stanley P. Farwell, *The Corona Produced by Continuous Potentials*, was presented, in the absence of the author, by Mr. F. W. Peek, Jr. It was discussed by Messrs. L.W.Chubb, A. E. Kennelly, Paul M. Lincoln, Max von Recklinghausen, L. T. Robinson, Selby Haar, and F. W. Peek, Jr.

After the close of the technical session, a smoker was held in the Institute rooms on the tenth floor.

Past Section Meetings

Baltimore.—October 28, 1914, Westport Power House. Inspection of the Westport Power House of the Consolidated Gas, Electric Light and Power Company of Baltimore, followed by a buffet luncheon. Joint meeting with Baltimore Consolidated Section of N. E. L. A. Attendance 280.

Boston.—October 21, 1914, Engineers Club Auditorium. Subject; Electric Cables. Short addresses were given on (1) "Electric Cable Design and Construction" by H. A. Morss, and (2)

"Cable Insulation" by W. S. Clark. Attendance 125.

Detroit-Ann Arbor.—October 23, 1914. Detroit Engineering Society Rooms. Subject; Electric Motors. Paper; "Commercial Forms of Polyphase Alternating-Current Motors and Their Proper Application" by A. H. Timmerman; illustrated by lantern slides. Attendance 61.

November 7, 1914, Laboratory, University of Michigan. Subject; Oscillograph. Paper; "Use of the Oscillograph in Electrical Investigation" by A. H. Lovell. Address by Mr. MacKavanagh on "Oscillogram Phenomena." Attendance 67.

Fort Wayne.—October 22, 1914, Commercial Club. Subject; Telephone Systems. Paper; 'Auto-Manual or Semi-Automatic Telephone Systems" by F. X. Staub. Attendance 11.

Indianapolis - Lafayette.—November 12, 1914, Shortridge High School, Indianapolis. Address by Mr. H. O. Garman on "Public Utility Evaluation." Election of officers as follows; chairman, J. Lloyd Wayne; vice-chairman, C. Francis Harding; secretary-treasurer, Walter A. Black; members executive committee, O. S. More and Alanson N. Topping. Attendance 35.

Ithaca.—October 23, 1914, Franklin Hall, Cornell University. Address by Mr. H. A. Hornor on "Electricity on Shipboard," illustrated by lantern slides. Attendance 80.

Los Angeles.—October 10, 1914, Eagle Rock Sub-Station. Inspection trip to Eagle Rock Substation of the Pacific Light and Power Corporation. Joint meeting with Engineers and Architects Association of Los Angeles. Attendance 107.

Lynn.—October 21, 1914, General Electric Works, West Lynn. Address by Prof. C. A. Adams on "The Induction Generator." Attendance 243.

November 14, 1914, General Electric Works, West Lynn. Address by Mr. W. A. Gladdings on "Some Glimpses of Government Ownership." Attendance 194.

Milwaukee.—October 21, 1914, Plankington House. Paper; "Electric Arc Welding" by J. H. Bryan. Illustrated talk by Dr. Nelson on "Protection for the Eyes During Arc Welding." Attendance 166.

Minnesota.—October 19, 1914, St. Paul, Minn. Report of Professor W. T. Ryan on Annual Convention of the Institute at Detroit, Mich. Attendance 19.

Panama.—October 25, 1914, Mount Hope Pumping Plant. Address by Mr. Geo. C. Bunker on "Rapid Sand Filtration," followed by illustration of filtration methods described in address. Attendance 16.

Philadelphia.—November 9, 1914, Engineers Club. Subject; Municipal Administration. Paper; "Some Experiences in Municipal Administration" by Clayton W. Pike. Attendance 95.

Rochester.—October 23, 1914. Election of officers as follows; chairman, John C. Parker; secretary-treasurer, O. W. Bodler; executive committee, Messrs. E. F. Davison, E. L. Wilder, Scott Lynn and F. E. Haskill. Attendance 78.

San Francisco.—October 23, 1914, Engineers Club. Paper; "Report of Joint Committee on Inductive Interference" by A. H. Griswold. Attendance 60.

Schenectady.—October 20, 1914, Edison Club Hall. Lecture by Dr. Ernst J. Berg on "Differential Equations Used in the Study of Transient Phenomena." Attendance 200.

November 3, 1914, Edison Club Hall. Election night smoker. Election returns were shown by means of lantern slides, followed by musical entertainment and light refreshments. Attendance 450.

November 17, 1914, Edison Club Hall. Subject; Methods of Photographic Investigation. Illustrated address by Dr. C. E. K. Mees. Attendance 400.

Seattle.—October 20, 1914, Rathskeller. Report on Annual Convention of the Institute at Detroit, Mich. Attendance 26.

St. Louis.—October 26, Public Library Building. Moving pictures in three reels on "The Manufacturing of Pipe from Iron Ore to the Finished Product." Film was explained by Mr. S. V. V. Hoffman, Jr. Attendance 100.

Toledo.—October 14, 1914, Ohio Electric Car Company. Inspection of plant of Ohio Electric Car Company, followed by paper on "The Electric Car" by Mr. H. P. Dodge. Attendance 22.

November 12, 1914, Toledo Commerce Club. Paper; "Electric Lighting and Starting for Automobiles," by A. E. Buchenberg. Attendance 35.

Urbana.—October 9, 1914, Physics Building, University of Illinois. Paper; "Interior Illumination" by Morgan Brooks. Attendance 100.

Past Branch Meetings

University of Arkansas.—October 19, 1914. Paper; "Automatic Block Signaling" by P. X. Rice. Attendance 12.

November 9, 1914, Engineering Hall. Papers; (1) "My Experience with Western Electric Company" by M. F. Jone, (2) "The Outlook for Young Engineers" by J. E. Bell. Attendance 11.

Armour Institute of Technology.—November 4, 1914, Lecture Room. Illustrated lecture by Mr. W. G. Martin on "The Artistic and Efficient Illumination of Interiors." Attendance 20.

Colorado State College.—September 25, 1914, Electrical Building. Election of officers as follows; chairman, George M. Strecker; secretary, E. O. Marks.

October 20, 1914, Electrical Building. Lecture by Prof. Rankin on "Electricity on the Farm." Joint meeting with Agricultural Club. Attendance 40.

November 10, 1914, Electrical Building. Lecture by Mr. Collopy on "Edison Storage Battery"; illustrated by lantern slides. Attendance 8.

Georgia School of Technology.—November 2, 1914, Chemical Lecture Room. Paper; "The Construction of the Hudson River Tunnels" by W. M. Torrance; illustrated by lantern slides. Attendance 92.

Iowa State College.—October 14, 1914. Election of officers as follows; chairman, Roscoe Schaffer; corresponding secretary, Frank A. Robbins. Attendance 9.

October 20, 1914. Short addresses on A. I. E. E. by Messrs. Roscoe Schaffer, P. C. Jansen, Elmer C. Gadown, Frank A. Robbins and Prof. L. B. Spinney. Attendance 92.

November 4, 1914. Papers; "Historical Sketch of the Development of the Electric Railway" by H. C. Bartholomew; and "The Future of the Alternating-Current System for Electric Railways" by Byron T. Mottinger. Attendance 49.

University of Kentucky.—October 28, 1914, Mechanical Hall. Papers; (1) "Design of Motors for Heavy Traction Work", (2) "Selection, Care and Operation of Carbon Brushes" and (3) "Risk Involved in Directing a Stream of Water onto a High-Tension Line." Attendance 29.

Lafayette College.—October 21, 1914, Pardee Hall. Papers; (1) "Ornamental Street Lighting," (2) "New Nitrogen-Filled Incandescent Lamp," and (3) "New York Electrical Show." Attendance 22.

November 11, 1914, Pardee Hall. Papers; (1) "Line Protection," (2) "25-Cycle vs. 60-Cycle Frequency for General Transmission Purposes." Attendance 21.

November 18, 1914, Pardee Hall. Papers; (1) "Types of Transmission Towers," (2) "Types and Makers of Insulators" and (3) "Electrical Equipment of Mill No. 4 of the Alpha Portland Cement Company." Attendance 21.

Lehigh University.—October 23, 1914, Physics Laboratory. Papers; (1) *Electrical Equipment of the Argentine Battleship Moreno*, and (2) "Trucks and Truck Batteries." Attendance 33.

University of Missouri.—October 26, 1914, Engineering Building. Papers; (1) "Construction Features of Trans-

mission and Distribution Lines," and (2) "Distributing Systems." Attendance 17.

November 9, 1914, Engineering Building. Papers; (1) "The Development of the Nitrogen-Filled Lamp," and (2) "Efficiency in Illumination." Attendance 23.

Montana State College.—October 23, 1914, Electrical Building. Address by Prof. Thaler on "Grading Students on Personal Characteristics." Attendance 31.

University of Nebraska.—November 4, 1914, Electrical Engineering Laboratory. Papers; (1) "Indirect Lighting Systems" by W. H. Stahl, and (2) "Sign Lighting" by Ivan M. Kirlin. Attendance 28.

North Carolina College of Agricultural and Mechanical Arts.—October 28, 1914. Illustrated talk by Mr. G. L. Jeffers on "Electrical Heating Apparatus."

November 10, 1914, West Raleigh. Demonstration lecture on "The Alternating-Current Magnet" by Messrs. H. M. Alexander and L. C. Rosser. Attendance 28.

Ohio Northern University.—October 21, 1914, Dukes Memorial. Papers; (1) "Submarine Signaling" by H. C. Doffins, and (2) "The Keokuk Plant" by W. F. Schott. Address on "Switchboards" by Mr. Bedell. Attendance 19.

November 4, 1914, Dukes Memorial. Papers; (1) "High-Tension Leads" by E. C. Vrohman, and (2) "Instrument Standardization" by R. E. Lowe. Attendance 11.

Oregon Agricultural College.—October 13, 1914, Corvallis. Short address by Prof. R. H. Dearborn.

November 3, 1914, Corvallis. Papers; (1) "Indicating Wattmeters," and (2) "Rotary Converters." Attendance 14.

Rensselaer Polytechnic Institute.—October 14, 1914, Sage Laboratory. Addresses were given on the following subjects; "A Transformer and Rotary Substation, Capacity 1000 Kw." by H. W. Ranney, and "Substation Practise in Connection with Steam Railroad Electrification" by W. E. Coover. Attendance 53.

Rhode Island State College.—October 28, 1914, Science Hall. Election of officers as follows; president, W. C. Miller; vice-president, A. P. Kivlin; secretary, P. M. Randall; treasurer, C. E. Siefert. Papers; "Industrial Power" and "Carbon, Tungsten and Nitrogen-Filled Lamps." Illustration by Prof. Coggins. Attendance 23.

Stanford University.—October 8, 1914, Electrical Engineering Building. Illustrated lecture by Mr. Hillebrand on "Electric Power Distribution." Attendance 30.

November 5, 1914, Electrical Engineering Building. Mr. W. L. Hood gave an interesting talk on "Trouble Shooting." Attendance 25.

Agricultural and Mechanical College of Texas.—October 16, 1914, Electrical Engineering Building. Papers; (1) "Armature Winding and Testing," and (2) "The New Turbine Testing Equipment of the General Electric Company at West Lynn." Attendance 39.

October 26, 1914, Electrical Engineering Building. Papers; (1) "Small Independent Refrigerator Plants," (2) "The Ozark Power Company's Plant on White River, near Forsyth, Mo.", and (3) "Itasca Station of the Texas Power and Light Company." Attendance 74.

November 6, 1914, Electrical Engineering Building. Papers; (1) "The History and Development of the Electric Railway," (2) "The Small Electric Heater," and (3) "A Description of the Ontario Power Plant." Attendance 45.

Washington University.—November 3, 1914. Illustrated lecture by Mr. C. B. Morgan on "The Industrial Safety Movement and Its Relation to the Engineer."

University of Washington.—November 4, 1914, Good Roads Building. Addresses; "The Design and Construction of a 200,000-Volt Transformer" by L. H. Dashley, and "The Design and Construction of the Government Locks

in Lake Washington Canal" by Mr. E. I. Pease. Attendance 37.

Worcester Polytechnic Institute.—November 13, 1914. Electrical Engineering Lecture Hall. Address by Mr. Thomas A. Watson on "The Birth of the Telephone." Attendance 200.

Yale University.—October 16, 1914. Paper; "Problems in the Electrification of the New Haven Road" by Mr. P. P. Winton. Attendance 70.

October 29, 1914, Electrical Laboratory. Paper; "Recent Developments in Large Power Plants" by H. G. Stott. Attendance 135.

Associates Elected November 13, 1914

ANTHONISEN, R. P., Student, Chicago Central Station Institute, Chicago; res., 122 Union St., Joliet, Ill.

BETCHER, BOID L., Chief Electrician, Union Pacific Coal Co., Rock Springs, Wyoming.

BIRDSALL, A. GLENTWORTH, Asst. in Commercial Dept., Lehigh Navigation Electric Co.; res., 438 Walnut St., S. Bethlehem, Pa.

*BISHOP, REMSEN, Wireman, Panama Canal, Pedro Miguel, C. Z.

DAVIDSON, JOSEPH F., Wireman, Panama Canal, Corozal, C. Z.

ENGLEHEART, PAUL, Superintendent, Guanajuato Power & Electric Co., Zamora, Mich., Mexico.

*GLASPEY, REXFORD M., Division Transmission Engineer, B. T. Co. of Pa., 19 S. 2nd St., Harrisburg, Pa.

GUNN, ARTHUR, President, Wenatchee Valley Gas & Electric Co., Wenatchee, Wash.

HOOK, EDWARD BURGESS, JR., Supt. of Pole Line Construction, Georgia Railway & Power Co., Atlanta, Ga.

HOPKINS, ALFRED H., Electrician, British Columbia Copper Co., Greenwood, B. C.

HOPPIN, GLENN H., Asst. to Supt. of City Distribution, Washington Water Power Co.; res., 2207 W. Mission Ave., Spokane, Wash.

HURST, ERNEST JOHNSON, Supt. Covington District, Georgia Railway & Power Co., Covington, Ga.

KLAPPER, CHARLES, Electrical Engineer, Toltz Engineering Co.; res., 260 W. 6th St., St. Paul, Minn.

*LONG, KUO-TSUN, Assistant Engineer, Tientsin Telephone Administration, Tientsin, China.

MAHAR, EARLE W., Inspector, Western Union Telegraph Co.; res., 330 Maple St., St. Paul, Minn.

MAMPLE, ADOLPH Z., Inspector, Plant Dept., Western Union Telegraph Co., Minneapolis; res., 402 E. Belvidere St., St. Paul, Minn.

MARKHAM, CARL W., Electrical Recorder, Panama Canal, Balboa Heights, C. Z.

MARSHALL, JAMES DREW, Assistant Engineer, Electric Construction Co.; res., 1774 Marshall Ave., St. Paul, Minn.

NORTH, CHARLES, Superintendent, Electrical Dept., Corporation of the City of Revelstoke; res., 57 5th St., E. Revelstoke, B. C.

PELLENS, FRANK T., Salesman, Westinghouse Electric & Mfg. Co., Birmingham, Ala.

PIRKL, ANTON J., Superintendent, Electric Construction Co., 174-178 E. 6th St., St. Paul, Minn.

PLAYER, GEORGE P., Telephone Engineer, Public Service Commission, Jefferson City, Mo.

RICKERBY, WILLIAM J., Engineer-Inspector, Dept. of Water Supply, Gas & Electricity, New York; res., 442 Gates Ave., Brooklyn, N. Y.

SIMPSON, RAY, General Manager and Electrical Engineer, Jewell Electrical Instrument Co., 810 West Lake St., Chicago, Ill.

STEARNS, JAMES E., Brooklyn Edison Company, 360 Pearl St., Brooklyn, N. Y.

STEWARD, C. P., Erection Department, Allis-Chalmers Mfg. Co., Milwaukee, Wis.

Suttor, John B., Jr., Manager, Australian General Electric Co., 217 Clarence St., Sydney, N. S. W., Australia.

Tarran, Leonard, Erector, Electrical & Mechanical Machinery, C. C. Moore & Co., 40 1st St., San Francisco, Cal.

Vowell, Christopher, Foreman, Electrical Dept., Messrs. Bull Bros., Port Ahuriri, Napier, New Zealand.

Total 29

*Former enrolled Students.

Students Enrolled November 13, 1914

6750 Giles, R. B., Univ. of Calif.
6751 Bass, L. B., Ga. Sch. Tech.
6752 Lessey, S. K., Yale University.
6753 Lyman, O. B., Yale University.
6754 Anschutz, E. B., Yale University.
6755 Tolles, R. P., Yale University.
6756 Fyler, L. K., Yale University.
6757 Robinson, L. B., Univ. of Wash.
6758 Ballew, W. W., Ga. Sch. Tech.
6759 Foster, J. L., A. & M. Col. of Tex.
6760 Oswald, A. A., Armour Inst. Tech.
6761 Thompson, H. J. Cornell University.
6762 Fye, H. F., Purdue University.
6763 Bruckmann, W., Purdue Univ.
6764 Hossellman. V. C., Purdue Univ.
6765 Cohen, H. F., Purdue Univ.
6766 Sun, C. T., Purdue University.
6767 Close, R. C., Purdue University.
6768 Hollzer, M., Univ. of Calif.
6769 Griffin, M. C., Univ. of Colo.
6770 Lynch, C R., Univ. of Colo.
6771 Dimmitt, C. E., Univ. of Kans.
6772 Walker, R. M., Univ. of Kans.
6773 Day, L. J., Univ. of Kansas.
6774 Keyser, G. M., Univ. of Kansas.
6775 Arnold, E. C., Univ. of Kansas.
6776 Thompson, A. R., Univ. of Cal.
6777 Rodig, M. T., Stanford Univ.
6778 Mulock, F. S., Stanford Univ.
6779 Cattell, G. W., Univ. of Cal.
6780 Critchfield, R. M., Ohio St. Univ.
6781 Whiting, D. F., Worcester Poly. Inst.
6782 Church, O. B., Lehigh Univ.
6783 Burns, T. S., Univ. of Wis.
6784 Doxsey, W. S., Case School App. Sci.
6785 Nelson, G. A., Univ. of Colo.
6786 Bergheim, M. N., Univ. of Colo.
6787 Floyd, F. N., Univ. of Colo.
6788 Robison, R. T., Univ. of Colo.
6789 Victory, T. M., Univ. of Colo.
6790 Borden, P. S., Univ. of Colo.
6791 Shugren, M. U., Univ. of Colo.
6792 Miller, C. S., Univ. of Colo.
6793 Condit, H. S., Univ. of Colo
6794 Flach, J J., Univ. of Colo.
6795 Clay, R. A., Ga. Sch. Tech.
6796 Green, S. G., Ga. Sch. Tech.
6797 Clements, B., Ga. Sch. Tech.
6798 Sipp, E. A., Univ. of Wis.
6799 Deyoe, H. L., Ore. Agri. Coll.
6800 Whitman, G. E., Univ. of Wis.
6801 Malone, C.B., Jr., Mass. Inst. Tech.
6802 Kuga, K., Univ. of Washington.
6803 Germain, W. A., Univ. of Wash.
6804 Drips, A. N., Univ. of Wash.
6805 Pedersen, E. A., Univ. of Wash.
6806 Joubert, L. P., Univ. of Wash.
6807 Worthington, H., Mass. Inst. Tech.
6808 Hern, G. P., Bucknell Univ.
6809 Morden, P. L., Univ. of Oregon.
6810 Pattee, C., Univ. of Oregon.
6811 Cuthbert, I. N., Univ. of Mich.
6812 Steck, C. C., Univ. of Mich.
6813 Zumbro, F. R., Univ. of Mich.
5814 Harning, J. F., Univ. of Mich.
6815 Reifsnider, J. M., Jr., Georgia School of Technology.
6816 Vaughan, V. G., Ga. Sch. Tech.
6817 Penton, E. W., Ohio State Univ.
6818 Lewisan, E. K., Iowa State Coll.
6819 McMeekin, G. D., Iowa St. Coll.
6820 Lee, A. E., Iowa State College.
6821 Cash, H. W., Iowa State College.
6822 Findlater, J. C., A. & M. Col. Tex.
6823 Deering, J. J., Armour Inst. Tech.
6824 Prochazka, R. V., Armour Inst. Tech.
6825 Boyajian, K. G., Swarthmore Coll.
6826 Schilling, J. T., Iowa State Coll.
6827 Ogilvie, V. A., Iowa State Coll.
6828 Meeker, H. C., Iowa State Coll.
6829 Shupe, M. N., Iowa State Coll.
6830 Butcher, C. A., Iowa State Coll.
6831 Kennedy, V. C., Mass. Inst. Tech.
6832 Apperson, A. L., Univ. of Oregon.
6833 Crutcher, F. B., Ga. Sch. Tech.
6834 Shoop, R. M., Penna. State Coll.
6835 Rankin, R. E., Penna. State Coll.
6836 Smith, H. S., Penna. State Coll.
6837 Wilson, C. E., Penna. State Coll.

6838 Winslow, D. E., Penna. State Coll.
6839 Valasek, J., Case Sch. App. Sci.
6840 Wickersheim, L. W., Univ. of Southern California.
6841 Gillilan, P. M., Ohio St. Univ.
6842 Goetchins, W. L., Wash. St. Coll.
6843 Moses, E. B., Tufts College.
6844 Black, A., McGill University.
6845 Butler, A. I., Iowa St. College.
6846 Willson, A. R., Univ. of Kansas.
6847 Markel, E. D., Univ. of Kansas.
6848 Goldsmith, E. L., Univ. of Wis.
6849 Fogerty, J. S., Mass. Inst. Tech.
6850 Jeans, J. H., Washington Univ.
6851 Roberts, P. C., Wash. Univ.
6852 Felker, P. H., Washington Univ.
6853 deCastro, N., Ohio Northern Univ.
6854 Evans, F. W., Ohio Northern Univ.
6855 Floyd, G. D., McGill University.
6856 Shand, E. B., McGill University.
6857 Storey, G. C., Univ. of Toronto.

Total 108.

Recommended for Transfer, November 5, 1914

The Board of Examiners, at its regular monthly meeting on November 5, 1914, recommended the following members of the Institute for transfer to the grades of membership indicated. Any objection to these transfers should be filed at once with the Secretary.

To the Grade of Fellow

Fries, Joens Elias, Assistant Engineer, Crocker-Wheeler Co., Ampere, N. J.

To the Grade of Member

Dawes, Chester Laurens, Instructor in Electrical Engineering, Graduate School of Applied Science, Harvard University, Cambridge, Mass.

Gupta, Birendra C., Professor of Electrical Engineering, C. E. College, Sidpur, India.

Turbayne, William A., Electrical Engineer, U. S. Light & Heating Co., Niagara Falls, N. Y.

Yates, William C., Commercial Engineer, Industrial Control Dept., General Electric Co., Schenectady, N. Y.

Applications for Election

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before December 30, 1914.

Allured, K. B., Harvey, Ill.
Atwell, R. N., Baltimore, Md.
Baddley, L. W., Cleveland, O.
Bager, H., Pittsfield, Mass.
Bardo, B. F., New Haven, Conn.
Beach, R., College Station, Tex.
Beckman, F. G., St. Louis, Mo.
Beil, E. H., Youngstown, O.
Belt, J. H., Urbana, Ill.
Berg, F. A., Philadelphia, Pa.
Biele, H. M., New York, N. Y.
Billhimer, F. M., E. Pittsburgh, Pa.
Blair, H. O., Tacoma, Wash.
Bothwell, C. C., Toronto, Ont.
Brink, H. S., Balboa Heights, C. Z.
Brown, G. O., Kansas City, Mo.
Buck, L., Rochester, N. Y.
Burr, G. A., E. Pittsburgh, Pa.
Byron, J. P., Spokane, Wash.
Cardiff, R. L., Santa Cruz, Cal.
Case, R. E., New York, N. Y.
Chrysler, W. L., Wilbur, Wash.
Coffin, F.A. (Member), Milwaukee, Wis.
Cone, D. I., San Francisco, Cal.
Cook, J. A., Chicago, Ill.
Correa, E. J., Los Angeles, Cal.
Corte, A., Schenectady, N. Y.
Deininger, H. F., Philadelphia, Pa.
Delvin, R. B., Detroit, Mich.
Doerschuk, H. M., Niagara Falls, N. Y.
Dubsky, F., Pittsfield, Mass.
Early, E., New York, N. Y.
Easler, J. M. T., San Francisco, Cal.
Eschler, R. T., Camden, N. J.
Etheridge, H. L., Van Nest, N. Y.
Frankel, M., Chicago, Ill.
Gates, A. B. (Member), Chicago, Ill.
Geist, H. F., Racine, Wis.

Gilchrest, G. I., Pittsburgh, Pa.
Glunt, S. J., Huntington, W. Va.
Gokay, W. M., Jackson, Mich.
Goldsmith, A. N. (Member), New York, N. Y.
Graves, A. G., Calgary, Alta.
Greves, G. L., Cleveland, O.
Griffiths, W. W., Fort Wayne, Ind.
Grimmenstein, A. W., Stanislaus, Cal.
Guild, E. S., Gatun, C. Z.
Gumaer, P. W., Columbia, Mo.
Hart, R. P., 2nd, New Haven, Conn.
Hattendorf, H. T., Gatun, C. Z.
Hawkins, H. B., Lynchburg, Va.
Hay, W. O., Jr., Sprigg, W. Va.
Hayes, D. W., Ann Arbor, Mich.
Hedstrom, E. S., Toronto, Ont.
Helm, W. A., Washington, D.C.
Hertz, S. S., E. Pittsburgh, Pa.
Hitchcock, H. W., New York, N. Y.
Hull, R. H., E. Pittsburgh, Pa.
Ingram, R. T., Hammond, Cal.
Jenks, H. G., Montpelier, Vt.
Jennings, C. E., Schenectady, N. Y.
Jennings, E. B., Iron River, Mich.
Johnson, A., Witton, England.
Kelso, N. T., Lafayette, Ind.
Kiehl, E. P., Philadelphia, Pa.
Killam, L., Milwaukee, Wis.
Kramer, H. A., San Francisco, Cal.
Laird, K. V., Berkeley, Cal.
Lamb, G. C., Worcester, Mass.
Lamb, I. C., Chicago, Ill.
Lassaff, B. W., Boston, Mass.
Lockert, W. H., Akron, Ohio.
Loebenstein, J. L., New York, N. Y.
Luster, E. W., Elizabeth, N. J.
Lustyk, F. J., Rochester, N. Y.
Lytle, B. H., E. Pittsburgh, Pa.
Mackay, R. C., Calgary, Alta.
Magee, J. W., Pittsburgh, Pa.
Markland, A. R., Altoona, Pa.
Marsh, J. D., E. Pittsburgh, Pa.
Marx, R. G., Stanford University, Cal.
Mavity, V. T., San Juancito, Honduras.
Mayer, E. C., Ithaca, N. Y.
Mayforth, J. H., Brooklyn, N. Y.
McCall, J. F., Calgary, Alta.
McEvoy, W., New York, N. Y.
McNally, J. H., Philadelphia, Pa.
Mehl, B. M., Sacramento, Cal.
Melcon, S. V., Preston, Idaho.
Michetti, O. D., Buenos Aires, A.R.
Mixson, A. M., Charleston, S. C.
Moody, M. R., Portland, Ore.
Morgan, F., Ann Arbor, Mich.
Morningstar, B. F., Cleveland, O.
Morrow, R. B., Spokane, Wash.
Moulton, V. C., E. Pittsburgh, Pa.
Mowry, R. Y., Chicago, Ill.
Murphy, E. B., San Francisco, Cal.
Murphy, W. V., Tallulah Falls, Ga.
Notley, G., Calgary, Alberta.
O'Connell, J. J. F., Glens Falls, N. Y.
Olson, E. F., Portland, Ore.
Pashek, A. L., Berea, O.
Penniman, A. L., Westport, Md.
Peterson, C. J., Somerset, Wis.
Popp, C. M., Lynn, Mass.
Powers, W. P., Pittsburgh, Pa.
Prior, A. A., Cambridge, Mass.
Pye, H. N., Newberry, S. C.
Quinn, E. A., (Member), Fresno, Cal.
RamSami, S. M., Bangalore, India.
Raney, E. C., Columbus, O.
Rath, A. J., Detroit, Mich.
Ready, L. S., San Francisco, Cal.
Reger, H. H., Gatun, C. Z.
Rickwood, H. A., Southampton, Eng.
Rommel, W. C., Philadelphia, Pa.
Rothmaler, O., New York, N. Y.
Royer, J. E. E., Spokane, Wash.
Rudolph, J. M., Calgary, Alta.
Ruekchi, H. A., Ft. Dodge, Ia.
Samuels, I., Allentown, Pa.
Saunders, H. O., Springfield, Ill.
Savant, D. P., Lafayette, Ind.
Shaper, S. R., Great Falls, Mont.
Shaw, F. R., Plainfield, N. J.
Sirnit, J. A., Birmingham, Ala.
Smith, J. R., Portland, Ore.
Snow, W. R., Napa, Cal.
Steeper, T. P., Warren, O.
Stemmons, B. L., Schenectady, N. Y.
Stiner, H. W., Pittsfield, Mass.
Stottler, M. W., E. Pittsburgh, Pa.
Sutherland, W. J. K., Rochester, N. Y.
Tappan, C. O. (Member), New York, N. Y.
Taylor, R. S., New York, N. Y.
Tripple, G., E. Pittsburgh, Pa.
Turner, F. F., Raleigh, N. C.
Waldhall, O. A., McFarland, Cal.
Wallis, C. T., Rochester, N. Y.
Warner, R. A., Schenectady, N. Y.
Weil, M. S., Hammond, Ind.

White, D. E., Seattle, Wash.
White, L. R., Chicago, Ill.
Wilcox, L. W., St. Paul, Minn.
Wilkinson, K. L., New York, N. Y.
Williams, E. H., Riverside, Cal.
Wines, H. D., Ann Arbor, Mich.
Yamawaki, M., Tokio, Japan.
Yeager, W. S., Stanislaus, Cal.
Yorkes, E. P., Philadelphia, Pa.
Yorke, L. P., Edmonton, Alta.
Young, C. A., Spokane, Wash.
Total 153.

EMPLOYMENT DEPARTMENT

NOTE: Under this heading brief announcements of vacancies, and men available, will be published without charge to members. Copy should be prepared by the member concerned and should reach the Secretary's office prior to the 20th of the month. Announcements will not be repeated except upon request received after an interval of three months; during this period names and records will remain in the office reference files. All replies should be addressed to the number indicated in each case, and mailed to Institute headquarters.

The cooperation of the membership by notifying the Secretary of available positions, is particularly requested.

Vacancies

The United States Civil Service Commission announces an open competitive examination for hydro-electrical engineer. From the register of eligibles resulting from this examination certification will be made to fill a vacancy in this position for service at Camp John Hay, Philippine Islands, and vacancies as they may occur in positions requiring similar qualifications, unless it is found to be in the interest of the service to fill a vacancy by reinstatement, transfer or promotion

The salary of this position is $2,400 per year and in addition transportation and expenses will be furnished from place of residence to the Philippines. Age of applicants—not less than 25 nor more than 45 years.

Persons who desire this examination should at once apply for the announcement of this position (Form No. 1097, issued November 10, 1914), Form 304, and special form, stating the title of the examination for which the forms are desired, to the United States Civil Service Commission, Washington, D.C., the Secretary of the United States Civil Service Board, Post Office, Boston, Mass., Philadelphia, Pa., Atlanta, Ga., Cincinnati, O., Chicago, Ill., St. Paul, Minn., Seattle, Wash., San Francisco, Cal.; Customhouse, New York, N. Y., New Orleans, La., Old Customhouse, St. Louis, Mo., or to the Chairman of the Porto Rican Civil Service Commission, San Juan, P.R. No application will be accepted unless properly executed, and filed with the Commission at Washington, with the material required, prior to the hour of closing business on December 15, 1914.

V-51. A large iron company has openings for two electrical men, preferably college graduates, with some experience, for service at its plant in Cuba. The plant includes an up-to-date direct-current installation, with a power house of 1500 kw. capacity and various motors and controllers required in connection with the ore treating and handling departments. Salary to begin, about $100 per month, depending somewhat on the experience of the applicants. It is the company's practise to give its American employees a vacation of six weeks with full pay, and transportation to and from New York.

Men Available

113. Graduate Electrical Engineer. Testing experience with the General Electric Co. Three years' design work on motors. Three years' commercial experience on industrial motors and control applications. Well acquainted with isolated plant practise. Can furnish excellent references.

114. Electrical Engineer. Graduate of a large western university; fifteen years with General Electric Co., principally in connection with preparation of specifications, estimates and drawings of power stations and foreign construction. Six years in India on high-voltage hydraulic power station construction and operation. Altogether nine years in the tropics. Preference foreign. References exchanged.

115. Young engineer, technical graduate, has had experience in repair work of locomotives and charge of several important tests; desires to locate near New York. At present employed.

116. Specialist in steam and hydroelectric power plant engineering, mechanical, electrical and civil; broad experience; economy and improvements in operation; takes charge of complete design and construction; reports on financial aspects; increases load factor; devises efficient methods to secure consumers for light and power.

117. Electrical and Hydraulic Engineer. Graduate of Mass. Institute of Technology. Experience in construction of electrical and hydraulic machinery in factories of this country and Germany; also fifteen years general consulting experience in the application of machinery for lighting, railway and industrial plants. Fellow A. I. E. E., Member A. S. M. E.

118. Sales Engineer. College graduate; 34 years old. Associate A.I.E.E., A.S.M.E. Specialist in efficient selling methods. Author of "Handbook of Instructions to Gas Appliance Salesmen." Experienced in closing large electric power contracts. Experienced sales manager for public utility company. Now open for a position with company desiring services of capable hardworking sales manager.

119. Mechanical and Electrical Engineer. Graduate Eastern university; fifteen years' experience building, operating electric light, railway plants; sales engineer for large manufacturing company; eight years efficiency and public utility engineer; desires to represent established manufacturing company in middle west, or valuation work for engineering firm. Now employed; can leave on short notice.

120. Electrical Engineer. University graduate; ten years' experience testing, assistant electrical engineer steel company; chief electrician large ice plant; also glass company. Planned, installed, and operated 6000-kw. power system, including substations. Will accept position as chief electrician industrial works or assistant electrical engineer power or light company.

121. Electrical Engineer. Experienced in designing, erecting, and maintaining electrical apparatus. Position in South preferred. At present occupied as chief engineer of a large land developing company. Highest references.

122. Electrical Engineer. Mass. Institute of Technology graduate. Broad experience in generation, transmission, and applications of power; ten years with General Electric Co., testing, designing and proposition engineering; also public utility companies. Has knowledge of principal foreign languages; some literary experience. Member A. I. E. E., A. S. M. E.

123. Technical graduate, thirteen years' practical experience in testing, estimating, specification work, power plant design, construction and maintenance, general and special engineering, etc., with large railway, light, power and engineering corporations in States and Canada; is willing to go anywhere in North or South America. Salary not of first importance.

124. Electrical Engineer. Open for engagement December first; twelve years' experience in design, supervision and construction of hydroelectric developments and electric transmission systems.

125. Purdue graduate, 1908, B. S. E. E. Desires position as sales manager with established concern handling or manufacturing electrical apparatus or equipment; several years' experience in sales; production work with one of the largest manufacturers of electric vehicles, with whom am still connected. Can furnish best of references.

126. Electrical Engineer. Six months' shop experience; seven months as electrical tester; two years in works management department of large electrical concern of the middle west; desires position where his experience can be used to advantage. Can furnish good references.

127. Electrical Engineer. Graduate (1910) of leading technical institute. Two years in apprenticeship course in various departments of Westinghouse Co.; sixteen months with railway company on power distribution; fifteen months inspecting electrical and mechanical apparatus. Position with railway or power company preferred. Past employers as references.

128. Electrical Engineer. University of Illinois, 1901; post-graduate, 1911. Degree E.E. and M.S. Thirteen years' practical experience testing, design, construction, operation; management steam electric and hydroelectric projects, including generation, high-tension transmission, distribution of power and light for mines and cities in U.S. and abroad. Best references. Now employed.

129. Electrical Construction Engineer. Eight years' experience in powerhouse and substation engineering; concrete bus-structure, man-hole building, etc., a specialty. Operation or construction position desired.

130. Electrical Engineer. Ph.B., Sheffield, Yale, 1910. Experienced in

house and factory wiring; one and a half years in General Electric machine shops, testing, drafting departments; three years with large high-tension hydroelectric plant; thoroughly familiar with operation, maintenance, construction of plant and transmission lines. Best references. Will consider anything Now employed.

131. Electrical Engineer, technical graduate. Three years testing with manufacturing and lighting companies. Three and a half years drafting on electric stations, electric motors, and steam turbines. One year on electrical construction. Three and a half years in engineering department of large electrical manufacturing company on developmental work.

132. Technical graduate, Assoc. A. I. E. E., Jr. A. S. M. E., thirty years old; experienced in public utilities, designing, construction, operating analyses, statistical work, property evaluations and reports. At liberty after December first. Excellent references; salary moderate.

133. Electrical Engineer, technical graduate. Three years' experience in interior construction, also line construction, seven years central station experience, including installation of apparatus, operation and maintenance of same; soliciting, collecting, etc. Desires position as superintendent of light and power company or other responsible position.

134. Mechanical and Electrical Engineer. Experience includes four-year apprentice course, machine trade, with Baldwin Locomotive Works; eighteen months testing department of Westinghouse Elec. & Mfg. Co., also drawing room, rate and estimating depts. Can give best of references.

135. Electrical Engineer, technical graduate. Desires position with light and power company, telephone company, or with consulting engineer. Eighteen months draftsman and assistant field engineer with telephone company; several months with light and power company as draftsman. Salary no consideration if position offers opportunity for advancement. Age 24. References furnished.

136. Electrical Engineer. Age 39, married. Four years foreign manufacturing and commercial engineering experience; nine years experience in steam railway electrification, estimating, installation and valuation. Hydroelectric management, construction and power sales experience. Executive report, valuation and management experience.

137. Electrical Engineer. Age 34; two-year engineering apprenticeship course, followed by ten years experience estimating energy requirements, selection of equipment, transmission and distribution calculations, and costs of railway electrification work; also operating experience in powerhouse and other efficiency work.

138. Sales Engineer. University and practical electrical engineering training. Two years G.E. test; four years general construction engineering and maintenance; central station and railway work. Three years successful sales work. Well acquainted large corporations Chicago and middle West, New York and East slightly. Now connected. Thirty, married, energetic; strong references.

139. General Manager and Electrical Engineer; technical graduate. Has had twenty-five years of railway construction and operation under all conditions. Possesses good ability, in an executive capacity, in the handling of men advantageously, in dealing with the public successfully. Until recently was General Manager for a railway and lighting company property.

140. Electrical Engineer. Lehigh graduate; eighteen months large electrical manufacturing concern; four years electrical engineer steel plant. Capable of taking charge of design, installation, operation of large industrial installations. Present position involves management of two power plants, machine shop, electrical repair shop, 300 men. Leave on reasonable notice. References.

141. Electrical Engineer. Graduate of Drexel Institute, Philadelphia. Five years' experience in substation and power house design and construction; two years on 60,000-kw., 110,000-volt receiving and distributing station. Can furnish best of references from prominent companies. Can leave on short notice.

142. Salesman and Motor Expert. Progressive young man; employed two and one-half years by Robbins & Myers Co., and two years Richmond Electric Works. Excellent record and substantial references.

143. Electrical Engineer. Fifteen years' experience erecting and installing powerhouse, substation and waterworks plants. All classes of electric machinery, storage batteries, telephones, armature winding, a-c. machine repairs, etc. Familiar with Westinghouse, General

Electric, Moloney and Siemens equipment. Well versed in theory; can design; estimate on power projects. Best references.

144. Electrical Engineer. Graduate Purdue, 1912. Two years with the General Electric Co.; one year in testing dept., one year in consulting engineering and transformer engineering depts., also two and a half years' experience in a small central station.

145. Draftsman. Eight years' experience in designing railway appliances and track devices. Age 29; at present employed, desire a change.

146. Manager-Engineer, open for employment after January 1, 1915. College graduate, competent, energetic, trustworthy, and a hustler, with commercial, engineering and executive ability. Seven years' experience in above work. Present employer may be referred to for references. Associate A.I.E.E., Member N.E.L.A. A real chance to secure a first-class man.

147. Electrical Engineer. Technical graduate, desires position with some manufacturing concern for designing and constructing experience. Two years in testing department of Western Electric Co. Have paid special attention to the construction of d-c. machinery. References furnished.

148. Works-Manager. Long experience in technical and executive work. Competent to take charge of mechanical, electrical or electrochemical plant Has been successful in installing workable production and cost systems, and in handling large numbers of men.

Library Accessions

The following accessions have been made to the Library of the Institute since the last acknowledgment.

American Handbook for Electrical Engineers. Compiled by a staff of specialists, Harold Pender, Editor-in-Chief, New York, 1914. (Purchase.)

Chicago Board of Supervising Engineers. Annual Report. 1912. Chicago, 1914. (Gift of Bion J. Arnold.)

Die geistigen Mittel des technischen Fortschrittes in den Vereinigten Staaten von Amerika. By Conrad Matschoss. Berlin, 1913. (Gift of author.)

General Electric Review. vol. 8, nos. 2-3. Schenectady, 1907. (Gift of W. D. Peaslee.)

Handbuch der Elektrizitat und des Magnetismus. By L. Graetz. Band III, pt. 1. Leipsig, 1914. (Purchase.)

Institution of Mechanical Engineers. Proceedings. 1914, pts. 1-2. London, 1914. (Exchange.)

Instruccao Technica nos Estados Unidos. By V. de Vivaldi-Coaracy. Porto Alegre, 1914. (Gift of author.)

Kinetic Theory of Gravitation, discussion of. By Chas. F. Brush. (reprinted from Proceedings of the American Philosophical Society. Vol. LIII, May 1914.) n.p. n.d. (Gift of author.)

McGraw Electrical Directory—Lighting & Power Edition, Oct. 1914. New York, 1914. (Purchase.)

National Physical Laboratory. Report for the year 1913-14. Teddington, 1914. (Exchange.)

——Collected Researches. vol. XI, 1914. London, 1914. (Exchange.)

New York (State) Public Service Commission, 1st District. Report. vol. III, 1912. New York, 1913. (Exchange.)

Ohio Public Utilities. Joint Committee on Valuation. Report 1914. (Gift of Joint Committee on Valuation.)

Principles of Electrical Measurements. By A. W. Smith. New York, 1914. (Purchase.)

Theta Xi Directory. 1914. New York, 1914. (Exchange.)

Gift of American Electric Railway Association.

District of Columbia. Public Utilities Commission. Annual Report, 1913.

Massachusetts Railroad Commission. General Laws of Massachusetts relating to railroad corporations, street railway companies and electric railroad companies. Boston, 1909.

Missouri. Public Service Commission. Annual Report 1st, 1913. Jefferson City, 1914.

New Jersey. Public Utility Commissioners, Board. Statistics of Public Utilities, 1912. Trenton, 1914.

Rhode Island. Public Utilities Commission. Annual Report 1913. Providence, 1914.

Gift of A. E. Kennelly.

Computation of Composite Alternating-Current Lines. By A. E. Kennelly. (Reprinted from Journal of Franklin Institute, Sept. 1914.)

Influence of Atmospheric Pressure upon the forced thermal convection from small electrically heated platinum wires. By A. E Kennelly and H. S. Sanborn. (Reprinted from Proc. American Philosophical Society, vol. liii, 1914.)

Model for Alternating-current Quantities. By A. E. Kennelly and H. G. Crane. (Reprinted from *Electrical World*, July 11, 1914.)

Resonance Tests of Long Transmission Line. By A. E. Kennelly and Harold Pender. (Reprinted from *Electrical World*, Aug. 8, 1914.)

TRADE CATALOGUES

Central Elec Co., Chicago, Ill. Central Electric discount and price book. Sept. 1914.

Coen Co., San Francisco, Cal. Catalog No. 1. "The Coen" system of mechanical oil burning. 1914.

Crane, Wm. M. Co., New York, N. Y. "Vulcan" Gas Appliances. Catalog.

General Electric Co. Schenectady, N. Y. Bulletin N. 40400. Belt driven alternators. Form PB. Sept. 1914.

——42500. Synchronous converters Sept. 1914.

——43320. Type W flame arc lamps for series and multiple circuits. Oct. 1914.

——No. 46018. Portable Voltmeter Type P-8. Oct. 1914.

——B-3317. Cords and portables, N. E. Code. Oct. 1914.

——Edison Lamp Works, Harrison, N. J. Bulletin No. 43603. High candlepower Edison Mazda lamps for standard lighting service. Sept. 1914.

Leeds & Northrup Co. Philadelphia, Pa. Bulletin No. 228. High sensitivity galvanometer.

——402. N.B.S. resistance standards.

Package Machinery Co., Springfield, Mass. Automatic machines for better wrapping of products. 31pp.

Steward & Romaine Mfg. Co., Philadelphia, Pa. Bull. No. 39. Bolts, drills, etc.

Union Iron Works Co., San Francisco, Cal. Liquid fuel mechanical oil-burning system "Dahl" patents. 1913.

Wagner Electric Manufacturing Co., St. Louis, Mo. Boletin 98. Boletin general. Nov. 1914.

Washington Engine Works, New York, N. Y. "White" mechanical fuel oil burning system. 31pp.

Western Electric Co., New York, N. Y. Boletin S. I. Cuadros conmutadores pequenos de Magneto. Nov. 1914.

Wirt Co., Germantown, Pa. Dim-a-lite. A turn down attachment for an electric lamp.

UNITED ENGINEERING SOCIETY

Association of Dominion Land Surveyors. Annual Report 7th, 8th 1913, 1914. Ottawa, 1913-14. (Gift of Association.)

Autogene Metallbearbeitung. vols. 1-6. Halle, 1908-1913. (Purchase.)

Gewerblich Technischer Rathgeber. vols. 1-6. Berlin, 1902-1907. (Purchase.)

Government Ownership of Telephones. By Mitchell Mannering. (Supplement No. 26 for Brief of Arguments against Public Ownership.) Reprint from National Magazine, July, 1914. (Gift of American Telephone & Telegraph Co.)

Graphic Methods for Presenting Facts. By W. C. Brinton. New York, 1914. (Purchase.)

Handbook of Tables and Formulas for Engineers. By C. A. Peirce and W. B. Carver New York, McGraw-Hill Book Co., 1914. (Purchase.)

Lackawanna Steel Company. Handbook, edition of 1915. Lackawanna, N. Y., 1914. (Gift of Company.)

Lehrbuch der Farbenchemie. By Hans Th. Bucherer. Leipzig, 1914. (Purchase.)

Lexikon der Papier-Industrie. Deutsch-Englisch-Französisch. 1905. Zurich, 1905. (Purchase.)

Der Motorwagen. vol. 1; vol. 2 (except nos. 10-11); vols. 3-9; vol. 10 (except no. 28); vol. 11; vol. 12 (except no. 2); vol. 13. Berlin, 1898-1910. (Purchase.)

The Naval Constructor. A vade mecum of ship design. Ed. 3. By George Simpson. New York, D. Van Nostrand Co., 1914. (Gift of Publishers.) Price $5.00.

This is the third edition of the author's work. It is replete with information of use to the naval constructor and contains much material which might be of great value to any engineer engaged in construction. The author has compiled much out-of-the-way information. W. P. C.

Simeon North, First Official Pistol Maker of the United States. A Memoir. By S. N. D. North and Ralph H. North. Concord, N. H., The Rumford Press, 1913. (Gift of S. N. D. North.)

Such monographs as this are too few in the United States; the majority of our people are too busy to make historical researches. Mr. North's record is very interesting, as bearing on the history of early American manufacturing. The Librarian wishes to thank the authors for this important contribution to a subject which has not received the attention it deserves. W. P. C.

Oil Paint and Drug Reporter. Green Book for Buyers. September 1914 edition. New York, 1914. (Gift of Oil, Paint & Drug Reporter.)

Primer of Scientific Management. Ed. 2. By Frank B. Gilbreth. New York, 1914. (Gift of author.)

The new edition is issued a little more than two years after the old one, showing a constant demand for an elementary treatise on the subject. W. P. C.

Sewerage. The designing, construction, and maintenance of sewerage systems. Ed. 6. By A. P. Folwell, New York, 1914. (Purchase.)

Some Problems in Concrete House Construction. By G. S. Mumford, 1914. (Gift of T. H. Boorman.)

Steel Working and Tool Dressing. By Warren S. Casterlin, New York, 1914. (Purchase.)

Der Verkehr (Jahrbuch des Deutschen Werkbundes, 1914.) Jena, 1914. (Purchase.)

War Map of American Trade Opportunities. 1914. (Gift of Alexander Hamilton Institute.)

Waterproofing—various applications and comparative costs. By T. H. Boorman. (Reprint from Proceedings of National Association of Cement Users, vol. V, 1909.) (Gift of author.)

What is wrong with the Telephone? By C. S. Goldman. Reprinted from "Nineteenth Century" Aug. 1914. (Gift of American Telephone and Telegraph Co.)

Zeitschrift fur Physikalische Chemie. vols. 1-82. Leipzig, 1887-1913.

Namen and Sachregister vols. 1-50. Leipzig, 1903-04, 1910-11. (Purchase.)

GIFT OF AMERICAN SOCIETY OF CIVIL ENGINEERS

Allison, J. E. Should Public Service Properties be Depreciated to obtain fair value in rate or regulation cases? Report to St. Louis Public Service Commission, Sept. 11, 1912.

Association of Ontario Land Surveyors. Annual Report 1913, 1914.

Canada. Department of the Interior. Report of Progress of Stream Measurements. 1912.

Canada. Department of Railways and Canals. Canal statistics for the season of Navigation. 1912.

Canada. Department of Public Works. Ottawa River Storage. Progress Report. 1909-1910.

Reports of the Ottawa River Storage and Geodetic Levelling from Halifax, N. S. to Rouses Point, N. Y. Vol. II, 1912.

Reports of the Ottawa River Storage and notes on a visit to the Panama Canal, also Geodetic Levelling between Stephens, Minn., and Winnipeg Beach, Man., Vol. II, 1913.

Chicago, Rock Island and Pacific Railway Company. Annual Report 33d, 1913.

Chicago, Milwaukee and St. Paul Railway Company. Annual Report 49, 50, 1913, 1914.

Classification of Operating Expenses of Carriers by Water, as prescribed by the Interstate Commerce Commission. Wash., 1910.

Connecticut. Rivers, Harbors and Bridges Commission. Report 1912.

Great Northern Railway Company. Annual Report 24, 1913.

Hawaii. Superintendent of Public Works. Report to the Governor for two years ending June 30, 1912.

Illinois and Michigan Canal. Special Report. 1912.

Indiana Sanitary & Water Supply Association. Proceedings of 6th Annual Convention. 1913.

Melan, J. Theory of Arches and Suspension Bridges. 1913.

Montana. State Engineer. Biennial Report. 1911-12.

National Association of Railway Commissioners. Select List of references on the Valuation of Public Service Corporations. n.d.

Nevada. Public Service Commission. Case No. U 15. City of Ely, complainant, vs. Ely Light and Power Company. 1913.

New Mexico. Surface Water Supply. Report 1911-12, 1913.

New Mexico. State Mine Inspector. Annual Report. 2d, 1913.

New South Wales. Metropolitan Board of Water Supply and Sewerage Report. 24, 1912.

New York State. Joint Committee of the Legislature on the Conservation and Utilization of Water Power. Report, 1913.

Ohio. Sewage Treatment and Trade Wastes. Report to the Director at Akron. 1912.

Ontario. Hydro-Electric Power Commission. Annual Report 5th, 1912.

Panama Railroad Company. Annual Report of the Board of Directors to the Stockholders. 64th, 1913.

Schussler, H. Past, Present and Future Water Supply of San Francisco. 1908.

——Water Supply of San Francisco, Cal. 1906.

Specifications for Maps and Profiles as prescribed by the Interstate Commerce Commission. 1914.

United States Steel Corporation. Annual Report 11th, 1912.

U. S. War Department. Report of the Governor of Porto Rico. 1913.

Utah. State Engineer. Biennial Report 7th, 1909-10; 8th, 1911-12.

Westinghouse Air Brake Co. Instruction pamphlet nos. 5027, 5028, 5030, 5032, 1907.

Wyoming. Geologist's Office. Bulletin nos. 5-7, Ser. B. 1913-14.

OFFICERS AND BOARD OF DIRECTORS, 1914-1915

PRESIDENT.

(Term expires July 31, 1915.)

PAUL M. LINCOLN.

JUNIOR PAST-PRESIDENTS.

(Term expires July 31, 1915.)	(Term expires July 31, 1916.)
RALPH D. MERSHON.	C. O. MAILLOUX.

VICE-PRESIDENTS.

(Term expires July 31, 1915.)	(Term expires July 31, 1916.)
J. A. LIGHTHIPE.	F. S. HUNTING.
H. H. BARNES JR.	N. W. STORER.
CHARLES E. SCRIBNER.	FARLEY OSGOOD.

MANAGERS.

(Term expires July 31, 1915.)	(Term expires July 31, 1916.)	(Term expires July 31, 1917.)
COMFORT A. ADAMS.	H. A. LARDNER.	FREDERICK BEDELL.
J. FRANKLIN STEVENS.	B. A. BEHREND.	BANCROFT GHERARDI.
WILLIAM B. JACKSON.	PETER JUNKERSFELD.	A. S. McALLISTER.
WILLIAM McCLELLAN	L. T. ROBINSON.	JOHN H. FINNEY.

TREASURER.	(Term expires July 31, 1915.)	SECRETARY.
GEORGE A. HAMILTON.		F. L. HUTCHINSON.

HONORARY SECRETARY.

RALPH W. POPE,
33 West 39th Street New York.

LIBRARIAN.

W. P. CUTTER,
29 West 39th Street, New York.

GENERAL COUNSEL.

PARKER and AARON,
52 Broadway, New York.

PAST-PRESIDENTS.—1884-1914.

*NORVIN GREEN, 1884-5-6.
*FRANKLIN L. POPE, 1886-7.
T. COMMERFORD MARTIN, 1887-8.
EDWARD WESTON, 1888-9.
ELIHU THOMSON, 1889-90.
*WILLIAM A. ANTHONY, 1890-91.
ALEXANDER GRAHAM BELL, 1891-2.
FRANK JULIAN SPRAGUE, 1892-3.
*EDWIN J. HOUSTON, 1893-4-5.
LOUIS DUNCAN, 1895-6-7.
FRANCIS BACON CROCKER, 1897-8.
A. E. KENNELLY, 1898-1900.
CARL HERING, 1900-1.
CHARLES P. STEINMETZ, 1901-2.
CHARLES F. SCOTT, 1902-3.
BION J. ARNOLD, 1903-4.
JOHN W. LIEB JR., 1904-5.
SCHUYLER SKAATS WHEELER, 1905-6
SAMUEL SHELDON, 1906-7.
HENRY G. STOTT, 1907-8.
LOUIS A. FERGUSON, 1908-09.
LEWIS B. STILLWELL, 1909-10.
DUGALD C. JACKSON, 1910-11.
GANO DUNN, 1911-12.
RALPH D. MERSHON, 1912-13
C. O. MAILLOUX, 1913-14.

*Deceased.

STANDING COMMITTEES

Revised to Dec. 1, 1914

EXECUTIVE COMMITTEE.

P. M. Lincoln, Chairman,
W. E. and M. Company, East Pittsburgh, Pa.
C. A. Adams, G. A. Hamilton,
H. H. Barnes, Jr., William McClellan,
B. A. Behrend, N. W. Storer.

FINANCE COMMITTEE

J. F. Stevens, Chairman,
1326 Chestnut St., Philadelphia, Pa.
H. H. Barnes, Jr. B. Gherardi.

LIBRARY COMMITTEE.

Samuel Sheldon, Chairman,
198½ Schermerhorn St., Brooklyn, N. Y.
B. Gherardi, Harold Pender,
F. L. Hutchinson, W. I. Slichter.

MEETINGS AND PAPERS COMMITTEE.

L. T. Robinson, Chairman,
General Electric Company, Schenectady, N. Y.
L. W. Chubb, H. H. Norris,
S. M. Kintner, C. P. Steinmetz,
and the chairmen of all technical committees.

EDITING COMMITTEE.

H. H. Norris, Chairman,
239 West 39th St., New York.
M. G. Lloyd, W. S. Rugg,
A. S. McAllister, W. I. Slichter.

BOARD OF EXAMINERS.

Maurice Coster, Chairman,
165 Broadway, New York.
Philander Betts, A. S. McAllister,
Henry Floy, John B. Taylor.

SECTIONS COMMITTEE.

H. A. Hornor, Chairman,
Hamilton Court, 39th and Chestnut Streets, Philadelphia, Pa.
Frederick Bedell, W. A. Hall,
H. W. Flashman, F. D. Nims.
Charles F. Scott,
and the chairmen of all Institute Sections.

STANDARDS COMMITTEE.

A. E. Kennelly, Chairman,
Harvard University, Cambridge, Mass
C. A. Adams, Secretary,
Harvard University, Cambridge, Mass.
James Burke, W. H. Powell,
W. A. Del Mar, Charles Robbins,
H. W. Fisher, L. T. Robinson,
H. M. Hobart, E. B. Rosa,
F. B. Jewett, C. E. Skinner,
P. Junkersfeld, J. M. Smith,
G. L. Knight, H. G. Stott,
W. L. Merrill, P. H. Thomas.

CODE COMMITTEE.

Farley Osgood, Chairman,
763 Broad Street, Newark, N. J.
J. C. Forsyth, A. M. Schoen,
H. B. Gear, George F. Sever,
Kempster B. Miller, H. O. Lacount,
H. N. Muller, C. E. Skinner,
H. R. Sargent.

LAW COMMITTEE.

G. H. Stockbridge, Chairman,
165 Broadway, New York.
Charles L. Clarke, Paul Spencer,
C. E. Scribner, Charles A. Terry.

SPECIAL COMMITTEES

Revised to Dec. 1, 1914.

POWER STATIONS.

H. G. Stott, Chairman,
600 West 59th Street, New York.
W. S. Gorsuch, C. S. MacCalla,
J. H. Hanna, R. J. S. Piggott,
C. A. Hobein, E. F. Scattergood.
A. S. Loizeaux, Paul Spencer,
C. F. Uebelacker.

TRANSMISSION COMMITTEE.

P. H. Thomas, Chairman,
2 Rector St., New York.
E. J. Berg, V. D. Moody,
P. M. Downing, F. D. Nims,
A. R. Fairchild, F. W. Peek, Jr.,
F. A. Gaby, Harold Pender,
L. E. Imlay, K. C. Randall,
L. R. Lee, C. S. Ruffner,
G. H. Lukes, F. D. Sampson,
Ralph D. Mershon, P. W. Sothman,
W. E. Mitchell, C. E. Waddell,
J. E. Woodbridge.

RAILWAY COMMITTEE.

D. C. Jackson, Chairman,
248 Boylston Street, Boston, Mass.
A. H. Armstrong, E. B. Katte,
A. H. Babcock, Paul Lebenbaum,
E. J. Blair, W. S. Murray,
H. M. Brinckerhoff, Clarence Renshaw,
E. P. Burch, A. S. Richey,
H. M. Hobart, F. J. Sprague,
N. W. Storer.

PROTECTIVE APPARATUS.

[Not yet appointed.]

ELECTRIC LIGHTING COMMITTEE.

Clayton H. Sharp, Chairman,
556 East 80th St., N. Y.
J. W. Cowles, H. W. Peck,
E. P. Hyde, S. G. Rhodes,
P. Junkersfeld, E. B. Rosa,
A. S. Loizeaux, G. H. Stickney,
T. S. Perkins, C. W. Stone.

INDUSTRIAL POWER COMMITTEE.

D. B. Rushmore, Chairman,
General Electric Company Schenectady, N. Y.
A. C. Eastwood, A. S. McAllister.
Walter A. Hall, J. P. Mallett,
J. M. Hipple, E. H. Martindale,
G. H. Jones, W. L. Merrill,
C. D. Knight, J. A. Osborn,
J. C. Lincoln, A. G. Pierce,
H. A. Pratt.

TELEGRAPHY AND TELEPHONY COMMITTEE.

C. E. Scribner, Chairman,
463 West Street, New York.
Minor M. Davis, K. B. Miller,
C. L. Fortescue, H. Mouradian,
H. M. Friendly, W. O. Pennell.
A. H. Griswold, F. L. Rhodes.
F. B. Jewett, John B. Taylor,
S. M. Kintner, J. L. Wayne,
William Maver, Jr. G. M. Yorke.

COMMITTEE ON USE OF ELECTRICITY IN MINES.

Wilfred Sykes, Chairman,
Box 242, East Liberty, Pa.
P. E. Alexander, M. H. Gerry, Jr.
C. W. Beers, Charles Legrand,
W. W. Briggs, K. A. Pauly.
Graham Bright, G. B. Rosenblatt,
B. T. Viall.

COMMITTEE ON USE OF ELECTRICITY IN MARINE WORK

C. S. McDowell, Chairman.
Navy Yard, New York.
Maxwell W. Day, H. A. Hornor,
W. L. R. Emmet, O. P. Loomis,
F. C. Hanker, D. M. Mahood,
H. L. Hibbard, Elmer A. Sperry,
Guy Hill, G. A. Pierce, Jr.,
F. W. Wood.

IRON AND STEEL INDUSTRY.

[Not yet appointed.]

ELECTROCHEMICAL COMMITTEE.

A. F. Ganz, Chairman.
Stevens Institute, Hoboken, N. J.
Lawrence Addicks, E. F. Price,
C. F. Burgess, C. G. Schluederberg,
Carl Hering, L. L. Summers.
W. R. Whitney,

ELECTROPHYSICS COMMITTEE.

J. B. Whitehead, Chairman,
Johns Hopkins University, Baltimore, Md
Frederick Bedell, E. L. Nichols,
H. L. Blackwell, E. B. Rosa,
L. W. Chubb, H. J. Ryan,
W. S. Franklin, H. Clyde Snook.

COMMITTEE ON RECORDS AND APPRAISALS OF PROPERTIES.

William B. Jackson, Chairman,
111 W. Monroe Street, Chicago, Ill.
Philander Betts, W. J. Norton,
William H. Blood, Jr., C. L. Pillsbury,
Fred A. Bryan, H. Spoehrer,
C. L. Cory, W. G. Vincent,
Clifton W. Wilder.

EDUCATIONAL COMMITTEE.

V. Karapetoff, Chairman.
Cornell University, Ithaca, N. Y.
E. J. Berg, A. S. Langsdorf,
F. L. Bishop, C. E. Magnusson,
C. R. Dooley, Charles F. Scott,
G. A. Hoadley, P. B. Woodworth.

PUBLIC POLICY COMMITTEE.

Calvert Townley, Chairman,
165 Broadway, New York.
H. W. Buck, H. A. Lardner,
Fredk. Darlington, William McClellan,
Gano Dunn, E. W. Rice, Jr.,
John H. Finney, L. B. Stillwell,
H. G. Stott.

PATENT COMMITTEE.

Ralph D. Mershon, Chairman,
80 Maiden Lane, New York.
Bion J. Arnold, O. S. Schairer,
C. S. Bradley, C. E. Scribner,
Val. A. Fynn, F. J. Sprague,
John F. Kelly, C. A. Terry.
H. Ward Leonard, E. S. Northrup.

MEMBERSHIP COMMITTEE.

H. D. James, Chairman,
W. E. and M. Company, East Pittsburgh, Pa.
Markham Cheever, A. G. Jones,
E. L. Doty, S. C. Lindsay,
Walter A. Hall, Herbert S. Sands,
Max Hebgen, M. S. Sloan,
H. A. Hornor, W. S. Turner,
P. B. Woodworth.

HISTORICAL MUSEUM COMMITTEE.

T. C. Martin, Chairman,
29 West 39th Street, New York
John J. Carty, E. W. Rice, Jr.,
Charles L. Clarke, Charles F. Scott,
Louis Duncan, Frank J. Sprague.

U. S. NATIONAL COMMITTEE OF THE INTERNATIONAL ELECTROTECHNICAL COMMISSION

C. O. Mailloux, President,
20 Nassau Street, New York
F. B. Crocker, Vice-Pres., A. E. Kennelly, Sec.,
Harvard University, Cambridge, Mass.
C. A. Adams, E. B. Rosa,
B. A. Behrend, C. F. Scott,
James Burke, C. H. Sharp,
Louis Bell, C. E. Skinner,
J. J. Carty, Samuel Sheldon,
Gano Dunn, Charles P. Steinmetz,
H. M. Hobart, H. G. Stott,
John W. Lieb, Elihu Thomson.
Philip Torchio.

COMMITTEE ON RELATIONS OF CONSULTING ENGINEERS.

L. B. Stillwell, Chairman,
100 Broadway, New York.
H. W. Buck, F. R. Ford,
Gano Dunn, F. N. Waterman.

COMMITTEE ON CODE OF PRINCIPLES OF PROFESSIONAL CONDUCT.

George F. Sever, Chairman,
13 Park Row, New York.
H. W. Buck, John F. Kelly,
Gano Dunn, Schuyler Skaats Wheeler.

NEW YORK RECEPTION COMMITTEE

Frederick C. Bates, Chairman,
30 Church Street, New York.
H. H. Barnes, Jr., William Maver, Jr.,
Edward Caldwell, Angus K. Miller,
N. A. Carle, F. A. Muschenheim,
W. G. Carlton, Farley Osgood,
W. A. Del Mar, H. A. Pratt,
Bancroft Gherardi, W. S. Rugg,
C. A. Greenidge, George F. Sever,
A. F. Ganz, Frank W. Smith,
E. W. Goldschmidt, P. W. Sothman,
A. H. Lawton, S. D. Sprong,
John W. Lieb, H. G. Stott,
R. R. Livingston, H. M. Van Gelder,
W. E. McCoy, J. M. Wakeman,
Robert H. Marriott, Walter F. Wells,
C. W. Wilder.

EDISON MEDAL COMMITTEE.

Appointed by President for terms of five years.

Term expires July 31, 1919.
Charles F. Brush, William Stanley,
N. W. Storer.

Term expires July 31, 1918.
H. W. Buck, J. Franklin Stevens,
F. A. Scheffler.

Term expires July 31, 1917.
A. E. Kennelly, H. Ward Leonard,
Robert T. Lozier.

Term expires July 31, 1916
Frank J. Sprague
Schuyler Skaats Wheeler, Chairman,
Ampere, N. J.
W. D. Weaver.

Term expires July 31, 1915.
Elihu Thomson, J. W. Lieb, Jr.,
E. L. Nichols.

Elected by the Board of Directors from its own membership for terms of two years.

Term expires July 31, 1915.
H. H. Barnes, Jr., William McClellan,
A. S. McAllister.

Term expires July 31, 1916.
C. E. Scribner, C. O. Mailloux,
L. T. Robinson.

Ex-Officio.
P. M. Lincoln, President.
George A. Hamilton, Treasurer.
F. L. Hutchinson, Secretary.

INSTITUTE REPRESENTATIVES

ON BOARD OF AWARD, JOHN FRITZ MEDAL

Dugald C. Jackson, Ralph D. Mershon,
Gano Dunn, C. O. Mailloux.

ON BOARD OF TRUSTEES, UNITED ENGINEERING SOCIETY.

Gano Dunn. Charles E. Scribner.
H. H. Barnes, Jr.

ON LIBRARY BOARD OF UNITED ENGINEERING SOCIETY.

Samuel Sheldon, Harold Pender,
B. Gherardi, W. I. Slichter,
F. L. Hutchinson.

ON ELECTRICAL COMMITTEE OF NATIONAL FIRE PROTECTION ASSOCIATION.

The chairman of the Institute's Code Committee,
Farley Osgood.

ON ADVISORY BOARD OF AMERICAN YEAR-BOOK.

Edward Caldwell.

ON ADVISORY BOARD, NATIONAL CONSERVATION CONGRESS.

Calvert Townley.

ON COUNCIL OF AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

W. S. Franklin. G. W. Pierce.

ON CONFERENCE COMMITTEE OF NATIONAL ENGINEERING SOCIETIES.

Calvert Townley, William McClellan.

ON JOINT COMMITTEE ON ENGINEERING EDUCATION.

Charles F. Scott, Samuel Sheldon.

ON AMERICAN ELECTRIC RAILWAY ASSOCIATION'S COMMITTEE ON JOINT USE OF POLES.

Farley Osgood, F. B. H. Paine,
Percy H. Thomas.

ON NATIONAL JOINT COMMITTEE ON OVERHEAD LINE CONSTRUCTION.

Farley Osgood, F. B. H. Paine,
Percy H. Thomas.

ON NATIONAL COMMITTEE ON ELECTROLYSIS.

Bion J. Arnold, F. N. Waterman,
Paul Winsor.

ON BOARD OF MANAGERS, PANAMA-PACIFIC INTERNATIONAL ENGINEERING CONGRESS, 1915.

A. M. Hunt. J. G. DeRemer.
And the President and Secretary of the Institute.

ON JOINT COMMITTEE ON REGISTRATION OF ENGINEERS

William McClellan, S. D. Sprong,

LOCAL HONORARY SECRETARIES.

Guido Semenza. N. 10, Via S. Radegonda, Milan, Italy.
Robert Julian Scott. Christ Church, New Zealand.
T. P. Strickland, N. S. W. Government Railways, Sydney, N. S. W.
L. A. Herdt, McGill Univ., Montreal Que.
Henry Graftio, Petrograd, Russia.
Richard O. Heinrich, Genest-str. 5 Schoeneberg, Berlin, Germany.
A. S. Garfield, 67 Avenue de Malakoff, Paris, France.

ON U. S. NATIONAL COMMITTEE OF INTERNATIONAL ILLUMINATION COMMITTEE

A. E. Kennelly, C. O. Mailloux,
Clayton H. Sharp.

LIST OF SECTIONS

Revised to December 1, 1914.

Name and when Organized.	Chairman	Secretary
Atlanta..............Jan. 19, '04	A. M. Schoen	H. M. Keys, Southern Bell Tel. & Tel. Co., Atlanta, Ga.
Baltimore............Dec. 16, '04	J. B. Whitehead	L. M. Potts, Industrial Building, Baltimore, Md.
Boston...............Feb. 13, '03	G.W. Palmer, Jr.	Ira M. Cushing, 84 State St., Boston, Mass.
Chicago......................1893	E. W. Allen	W. J. Norton, 112 W. Adams St., Chicago, Ill.
Cleveland............Sept. 27, '07	Howard Dingle	R. E. Scovel, 1663 East 86th Street, Cleveland, Ohio.
Detroit-Ann Arbor....Jan. 13, '11	H. H. Norton	Ray K. Holland, Cornwell Building, Ann Arbor, Mich.
Fort Wayne..........Aug. 14, '08	L. D. Nordstrum	J. J. A. Snook, 927 Organ Avenue, Ft. Wayne, Indiana.
Indianapolis-Lafayette..........Jan. 12, '12	J. L. Wayne, 3d.	Walter A. Black, 3042 Graceland Ave., Indianapolis, Ind.
Ithaca...............Oct. 15, '02	E. L. Nichols	W. G. Catlin, Cornell University, Ithaca, N.Y.
Los Angeles..........May 19, '08	C. G. Pyle	Edward Woodbury, Pacific Lt. & Pr. Company, Los Angeles, Cal.
Lynn.................Aug. 22, '11	W. H. Pratt	F. S. Hall, General Electric Co., Lynn, Mass.
Madison..............Jan. 8, '09	J. W. Shuster	F. A. Kartak, Univ. of Wisconsin, Madison, Wis.
Mexico...............Dec. 13, '07		
Milwaukee............Feb. 11, '10	L. L. Tatum	W. J. Richards, National Brake and Electric Co., Milwaukee, Wis.
Minnesota............Apr. 7, '02	Leo H. Cooper	Emil Anderson, 1236 Plymouth Bldg., Minneapolis, Minn.
Panama...............Oct. 10, '13	Hartley Rowe	Clayton J. Embree, Balboa Heights, C. Z.
Philadelphia.........Feb. 18, '03	H. F. Sanville	W. F. James, 1115 North American Bldg., Philadelphia, Pa.
Pittsburgh...........Oct. 13, '02	J. W. Welsh	Charles R. Riker, Electric Journal, Pittsburgh, Pa.
Pittsfield...........Mar. 25, '04	W. W. Lewis	M. E. Tressler, General Electric Company, Pittsfield, Mass.
Portland, Ore.........May 18, '09	R. F. Monges	Paul Lebenbaum, 45 Union Depot, Portland, Ore.
Rochester............Oct. 9, '14	John C. Parker	O. W. Bodler, Pittsford, N. Y.
St. Louis............Jan. 14, '03	S. N. Clarkson	A. McR. Harrelson, 5929 DeGiverville Avenue, St. Louis, Mo.
San Francisco........Dec. 23, '04	C. J. Wilson	A. G. Jones, 819 Rialto Building, San Francisco, Cal.
Schenectady..........Jan. 26, '03	H. M. Hobart	S. M. Crego, Gen. Elec. Co., Schenectady, N. Y.
Seattle..............Jan. 19, '04	S. C. Lindsay	E. A. Loew, University of Washington, Seattle, Wash.
Spokane..............Feb. 14, '13	J. W. Hungate	L. N. Rice, Parsons Hotel, Spokane, Wash.
Toledo...............June 3, '07	George E. Kirk	Max Neuber, Cohen, Friedlander & Martin, Toledo, O.
Toronto..............Sept. 30, '03	D. H. McDougall	H. T. Case, Continental Life Bldg., Toronto, Ont.
Urbana...............Nov. 25, '02	I. W. Fisk	P. S. Biegler, University of Illinois, Urbana, Illinois.
Vancouver............Aug. 22, '11	F. D. Nims	K. C. Auty, B. C. Electric Railway Co. Ltd., Vancouver, B. C.
Washington, D. C......Apr. 9, '03	C. B. Mirick	C. A. Peterson, 1223 Vermont Ave., N. W. Washington, D. C.

Total 31

LIST OF BRANCHES

Name and when Organized	Chairman	Secretary
Agricultural and Mech. College of Texas.....Nov. 12, '09	J. F. Nash	A. Dickie, A. & M. College, College Station, Tex.
Arkansas, Univ. of.,....Mar. 25, '04	D. C. Hopper	J. E. Bell, Univ. of Arkansas, Fayetteville, Ark.
Armour Institute.......Feb. 26, '04	W. L. Burroughs	Chester F. Wright, 3341 Michigan Boulevard, Chicago, Ill.
Bucknell University....May 17, '10	F. O. Schnure	J. M. Hillman, Bucknell University, Lewisburg, Pa.
California, Univ of.,....Feb. 9, '12	L. R. Chilcote	E. S. Meddaugh, 2521 Channing Way, Berkeley, Cal.
Cincinnati, Univ. of.....Apr. 10, '08	M. L. Harned	A. C. Perry, University of Cincinnati, Cincinnati, O.
Clemson Agricultural College..............Nov. 8, '12	F. J. Jervey	F. H. McDonald, Clemson College, S. C.
Colorado State Agricultural College........Feb. 11, '10	George M. Strecker	E. O. Marks, Colorado State Agricultural College, Fort Collins, Colo.

LIST OF BRANCHES—Continued.

Name and when Organized	Chairman	Secretary
Colorado, Univ. of., ... Dec. 16, '04	Philip S. Borden	Charles S. Miller, University of Colorado, Boulder, Colo.
Georgia School of Technology .... June 25, '14	R. A. Clay	J. M. Reifsnyder, Jr., Georgia School of Technology, Atlanta, Ga.
Highland Park College Oct. 11, '12	Clyde Prussman	Ralph R. Chatterton, Highland Park College, Des Moines, Iowa.
Idaho, University of .... June 25, '14		
Iowa State College ..... Apr. 15, '03	Roscoe Schaffer	F. A. Robbins, Iowa State College, Ames, Iowa.
Iowa, Univ. of., ... May 18, '09		A. H. Ford, University of Iowa, Iowa City, Iowa.
Kansas State Agr. Col.,. Jan. 10, '08	L. V. Fickle	Clarence E. Reid, Kansas State Agric.Col., Manhattan, Kan.
Kansas, Univ. of., ... Mar. 18, '08	H. C. Hansen	L. M. Bocker, Univ. of Kansas, Lawrence, Kansas.
Kentucky State Univ. of Oct. 14, '10	Harry Y. Barker	G. F. Campbell, 345 South Limestone Street, Lexington, Ky.
Lafayette College ...... Apr. 5, '12	R. McManigal	W. J. English, Jr., Lafayette College, Easton Pa.
Lehigh University, ... Oct. 15, '02	N. F. Matheson	F. C. Brockman, 3 North Main St., Nazareth, Pa.
Lewis Institute, ... Nov. 8, '07	A. H. Fensholt	Fred A. Rogers, Lewis Institute, Chicago, Ill.
Maine, Univ. of., ... Dec. 26, '06		
Michigan, Univ. of., ... Mar. 25, '04	H. A. Enos	H. W. Stubbs, University of Michigan, Ann Arbor, Mich.
Missouri, Univ. of., ... Jan. 10, '03	E. W. Kellogg	K. Atkinson, University of Missouri, Columbia, Mo.
Montana State Col., ... May 21, '07	John M. Fiske	J. A. Thaler, Montana State College, Bozeman, Mont.
Nebraska, Univ. of ..... Apr. 10, '08	Olin J. Ferguson	V. L. Hollister, Station A, Lincoln, Nebr.
New Hampshire Col. ... Feb. 19, '09		
North Carolina Col. of Agr., and Mech. Arts ...... Feb. 11, '10	A. C. Fluck	R. Crowder, West Raleigh, N. C.
North Carolina, Univ. of Oct. 9, '14	P. H. Daggett	J. W. McIver, University of North Carolina, Chapel Hill, N. C.
Ohio Northern Univ., ... Feb. 9, '12	R. E. Lowe	W. F. Schott, 426 South Union Street, Ada, Ohio.
Ohio State Univ., ... Dec. 20, '02	Leslie J. Harter	Robert C. Schott, 38 14th Avenue, Columbus, Ohio.
Oklahoma Agricultural and Mech. Col .... Oct. 13, '11	A. P. Little	Quentin Graham, 118 Husband St., Stillwater, Okla.
Oklahoma, Univ. of., ... Oct. 11, '12	C. K. Karcher	W. Miller Vernor, Univ. of Oklahoma, Norman, Okla.
Oregon, Agr. Col., ... Mar. 24, '08	W. R. Grasle	Winfield Eckley, Oregon Agric. Col., Corvallis, Ore.
Penn State College ..... Dec. 20, '02	H. S. Smith	
Pittsburgh, Univ. of., ... Feb. 26, '14	B. E. O'Hagan	George Hickman, University of Pittsburgh, Pittsburgh, Pa.
Purdue Univ., ... Jan. 26, '03	L. W. Spray	R. E. Tafel, Purdue Univ., Lafayette, Ind.
Rensselaer Poly. Inst. .. Nov. 12, '09	W. J. Williams	W. E. Coover, 74 Eagle Street, Troy, N.Y.
Rose Polytechnic Inst., Nov. 10, '11	Charles F. Harris	Claude A. Lyon, 1331 Liberty Avenue, Terra Haute, Ind.
Rhode Island State Col. Mar. 14, '13	W. C. Miller	P. M. Randall, Jr., Rhode Island State College, Kingston, R. I.
Stanford Univ., ... Dec. 13, '07	G. L. Beaver	H. J. Scholz, Stanford University, Cal.
Syracuse Univ., ... Feb. 24, '05	W. P. Graham	R. A. Porter, Syracuse University, Syracuse, N. Y.
Texas, Univ. of., ... Feb. 14, '08	J. M. Bryant	J. A. Correll, University of Texas, Austin, Tex.
Throop College of Technology .... Oct. 14, '10	W. L. Newton	A. W. Wells, Throop Poly. Institute, Pasadena, Cal.
Virginia, Univ. of. ...... Feb. 9, '12	W. S. Rodman	H. Anderson, Jr., 1022 West Main St., Charlottesville, Va.
Wash., State Col. of .... Dec. 13, '07	M. K. Akers	H. V. Carpenter, State Coll. of Wash., Pullman, Wash.
Washington, Univ. of., ... Feb. 6, '04	C. C. Hardy	Charles P. Seeger, Washington University, St. Louis, Mo.
Washington, Univ. of.,. Dec. 13, '12	H. W. McRobbie	B. B. Bessesen, Univ. of Washington, Seattle, Wash.
West Virginia Univ. .... Nov. 13, '14	H. C. Schramm	C. L. Walker, West Virginia Univ., Morgantown, W. Va.
Worcester Poly. Inst., . Mar. 25, '04	Frank Aiken	A. B. R. Prouty, Worcester Poly. Inst., Worcester, Mass.
Yale University .... Oct. 13, '11	F. M. Doolittle	K. Lessey, 106 Van. Sheff, New Haven, Conn.

Total 50

SECTION II

PROCEEDINGS

of the

American Institute

of

Electrical Engineers

Papers, Discussions and Reports

CONTENTS OF SECTION II

DISCUSSION ON "SOURCES OF POWER FOR ELECTROCHEMICAL PROCESSES" (NEWBURY), NEW YORK, JANUARY 9, 1914.* (SEE PROCEEDINGS FOR JANUARY, 1914.)

(Subject to final revision for the Transactions)

G. A. Roush: Mr. Newbury takes up a standard outfit, with a capacity of 120,000 h.p., and draws comparisons on that basis. I think it would have been, possibly, of more value to the people interested in the electrochemical utilization, to have used for examples sizes of installations that are more nearly those that are actually in use, that is, as Mr. Addicks stated in his paper, in the neighborhood of 1000 to 1500 kw.

F. A. Lidbury: In only one line of electrolytic industry—the reduction of aluminum—are single installations of 120,000 h.p. conceivable at the present time; indeed, there is no other single line of electrolytic manufacture, the power requirements of which throughout the United States exceeds 100,000 h.p. and the instance of water power generation examined by Mr. Newbury is so far removed from anything approaching what is possible in the refining of copper and the other metals, that his analysis has practically no bearing. Most electrolytic plants of importance, the aluminum industry being excluded, will be found to have a power consumption somewhere between 1000 h.p. and 10,000 h.p., and so far from single units of 5000 kw. being common, any plant which is consuming 5000 kw. will be found to be, even today, a considerable factor in its particular line of manufacture. Even in the largest electrolytic installations (still excepting aluminum plants) the size of units does not often exceed 1000 kw. Most electrochemists would, therefore, have been more interested in comparisons made between installations of units of capacities of this order than in those with which Mr. Newbury specifically dealt in considering water power generation. That the results of such a comparison would have been very different is clear from a consideration of his own data; it will no longer be correct to say that "in very few plants can water wheel generators be located near enough to the electrochemical plant to justify the installation of direct current generators." It is obviously true that where transportation or other conditions demand the location of the electrolytic plant at a considerable distance from the power house, d-c. generation will be out of the question in any case, but where no such condition is involved, it will usually be found not only feasible but the only rational scheme.

Having somewhat modified our starting point in regard to the size of unit which should be taken as typifying electrolytic

*At this joint meeting two other papers were presented, " (1) "Limitations of the Problem of Electrolytic Deposition," by Lawrence Addicks, of the American Electrochemical Society, and (2) "The Mechanical Side of Problem," by H. E. Longwell, of the American Society of Mechanical Engineers. These papers are published by the societies mentioned and not by the A. I. E. E.

requirements, Mr. Newbury's table connecting the prime mover and generator speed with the conservatively practicable capacity of units, assumes quite another aspect; it teaches us that d-c. generators of 1000 kw. capacity can be directly connected to waterwheels of speeds as high as 600, if a voltage of 250 is used, and as high as 300 in the extreme case of voltage requirements as low as 125. Obviously, under typical conditions, there ceases to be any difficulty in d-c. generation in connection with any waterwheel speed that is likely to be met with. This, in turn, puts quite a different aspect upon the comparative efficiency of d-c. generation and a-c. generation with converters, as is obvious from the fact that the bulk of the difference in overall efficiencies from water to load in Mr. Newbury's table is accounted for by the necessity of adopting, under the conditions which he examines, a turbine of lower speed and of 9 per cent lower efficiency for connection to the d-c. generator. Under conditions more truly typical, this necessity vanishes. It will usually be found advisable under these conditions to require no modification of water wheel speed to accommodate either alternator or d-c. generator, as there will be no difficulty in obtaining either machine to give first rate performance at the speed most advantageous from the point of view of water wheel design. As a general rule it will be found much easier to get the electrical manufacturer than the turbine maker to make what compromises are necessary without appreciable loss of efficiency. There will, in any case, be but a slight difference in efficiency of a-c. and d-c. generators, probably not exceeding one per cent, and while there may be a considerable difference in cost between d-c. and a-c. units, the magnitude of this will depend upon a number of conditions, chief of which is the d-c. voltage; under favorable conditions, *e. g.*, where d-c. voltages approaching or exceeding 250 can be used, the cost of a-c. accessories (exciters, switching equipment, etc.) will go far towards completely wiping out this difference. In most cases, therefore, it is practically a question of determining the distance to which the value of the synchronous converter set with transformers and accessories, and including building space and investment in copper, will enable the current to be carried with the same per cent energy loss as that involved in transformation by the synchronous converter set; and perhaps it would be only in accord with experience to carry out this calculation with a healthy skepticism as to whether the overall efficiency of a-c. generation and converters as expressed by the product of the efficiencies of the component parts of the system under test conditions will not be appreciably reduced under conditions of actual operation. Viewed from this standpoint, the radius of economic transmission of low-tension direct current will often figure out surprisingly large, and will, in almost every instance in which it is not necessary to place the load at a point determined by other considerations,

usually be sufficient to include not only a possible point of delivery to the load, but also the whole of the load-absorbing portion of the plant, within its area.

Economically, at least, two other points are to be considered. It is obvious that direct operating cost (*e.g.* attendance, oil, etc.) will in some respects be practically doubled by the necessity of maintaining two stations containing moving machinery, instead of one; and maintenance charges will also be considerably increased, though possibly not to the same extent. The smaller the installation, the more important this point becomes. Secondly, due weight must be given to the difference in depreciation on the same sum invested, respectively in copper conductors and in synchronous converter equipment. This difference would be likely to appear more clearly at the end of a number of years' running than in the early stages of the installation. One cannot, of course, prophesy what the scrap price of copper is likely to be in 10 or 15 years time, but one has a pretty good idea of what the scrap price of a synchronous converter equipment of that age is likely to be. Both these factors have to be included in any proper scheme of economy, and they are not by any means insignificant in magnitude.

Lastly, the electrochemical engineer is also apt to have a prejudice in favor of simplicity. What he wants in the way of power equipment is something which will be primarily characterized by smoothness, ease and reliability in operation, and he is apt to know by experience that this is not most likely to be obtained by multiplying the electrical links in his chain of power machinery, or the number of points needing continual attention to insure the best operating results.

I frankly concede that these remarks do not apply to water power installations of such magnitude as Mr. Newbury deals with, and I also concede that he has pointed out that the validity of his conclusions decreases with decrease of unit capacity. It seemed highly desirable, however, that this portion of the subject should be discussed in its bearing upon the vast majority of electrolytic installations.

F. L. Antisell: It seems that one point which has been overlooked is the efficiency of partial loads. The reciprocating engine is capable of having the characteristic of the 100 per cent load, by varying the speed of the engine, tending to uniform mean effective pressure. In the various types of turbines, when we come to running at partial loads, we find a great falling off in efficiency. I do not think this point has been brought out fully, and it is a very important point in connection with this subject.

J. B. F. Herreshoff: Our system at first apparently required small units, and those were supplied with high-speed triple-expansion engines of the torpedo type. They were first installed about 15 years ago, in units of about 400 kw., making 350 rev. per min., operated condensing. Those were after-

wards operated with a low-pressure turbine. The engines gave very satisfactory results, but the cost of maintenance on a great many units is an item that we have to avoid. The first of the turbo-generators that we had was the first one of the Parsons type made in the United States, running about 5000 to 6000 rev. per min., generating direct current, and it had very long commutators. After that we put in a cyclic generator of 2000 kw., but we had trouble with the collectors. We found an enormous amount of heat going away from the machines, and inasmuch as it came out of four or five holes, it was a simple problem to take the temperature of the ingoing and outgoing air. We found that 30 per cent of the energy was going off in heat.

We also felt there must have been some mistake in the method heretofore used in arriving at the efficiency of this machine, which was supposed to run up to ninety-five per cent, but this method of getting at the efficiency seemed to be a pretty good one.

The next problem was how to get the best arrangement for making an alternating current, starting first with the steam turbine. Mr. J. B. Herreshoff conceived the idea of an alternating-current generator of a low voltage, connected without any transformer to a properly designed synchronous converter. A good many of these outfits have been built and they seem to have special advantages for this type of work.

J. B. Herreshoff: In an electrolytic plant, if you double the amperes you will deposit your copper in half the time. This will take double the voltage, and the result would be you would have four times the power in your tanks. There are some advantages in doing this. The temperature of the electrolyte would be kept up, and in some cases it might not be necessary to use steam. This is done at Great Falls. At that plant I believe they use a current density of about 40 amperes per sq. ft. (0.09 sq. m.), and the temperature of the electrolyte there is 150 deg. fahr. In the multiple system, the temperature will vary generally in the East here from 130 to 135 deg. fahr. The cost of keeping the electrolyte warm is so great that the temperature can not very well be kept higher.

It is interesting to note that if we do double the current density, although the power goes up four times, the cost per pound of copper only doubles. The objection to doing this, we have found, is that the deposits are not so smooth; they are apt to be crystalline, more brittle, which is often a very serious matter in the handling of the cathodes.

Mr. Newbury mentioned that it was very easy to vary the voltage, where there was only one synchronous converter connected with one alternator, by varying the field of the alternator. This is true. It can also be varied, to some extent, by varying the length of the synchronous converter, which has the effect of changing the power factor. Where two con-

verters are connected to one alternator, differences of voltage can be obtained by weakening the field of one slightly, and strengthening the field of the other. The advantage of doing this is that you can use a larger turbine and alternator which, of course, means a little more cost in installation, but it also means a little better economy. The objection to this method of control is that on account of the power factor not being unity, the converter will heat up in some parts of the armature, but not seriously, if the difference of voltage between the rotaries is not more than thirty or forty.

C. O. Mailloux: The statement which has been made that the character of the copper deposit depends upon the current density requires some qualification. That it is true in cases such as those which have been referred to is due to the peculiar circumstances and conditions of the cases. It is not true as a general proposition, and the wide-spread belief that a regular deposit of ductile copper of good quality can be obtained only with low current-densities is quite erroneous. The quality of the copper deposited at the cathode may be independent of the current-density within very wide limits. It is possible to obtain very good deposits, (and also very bad deposits) at any current-density between 10 and 1000 amperes per sq. ft. (0.09 sq. m.). A current-density of 1000 amperes per sq. ft. will doubtless seem enormous to those who are familiar only with the current-densities employed in electrolytic copper refining, which seldom exceed 30 amperes per sq. ft.; but it is true, nevertheless, that copper-deposits of the finest quality can be obtained at that high current-density. In 1885, I was called upon to develop a process of rapid electrotyping. Electrolytic copper "shells" such as used for making ordinary electrotypes have a thickness ranging from 0.010 to 0.015 inch (0.25 to 0.38 mm.). This means a weight ranging between 0.45 and 0.70 lb. per sq. ft., and the quantity of current required to deposit that amount of copper, allowing for some loss in current-efficiency, *i.e.*, allowing for electrolytic action which causes the deposit of something else besides copper—hydrogen, for instance—at the cathode, will range between 200 and 300 ampere-hours per sq. ft. With a current-density of only 10 amperes per sq. ft., the time required will therefore be from 20 to 30 hours. The problem which I was called upon to solve was to shorten the time to not over two hours. It was important that the copper shells should be very uniform in thickness, free from "pin-holes", and of the very best quality of copper. Considering their large size—that of a newspaper page—it seemed difficult to meet these requirements. It proved possible, however, to obtain deposits of the finest quality and uniformity with current-densities as high as 1000 amperes per sq. ft. This enabled the time to be cut down to less than one-half hour for a shell of full thickness; but for the purpose in view a rate of deposit producing a shell in one hour was sufficient and was adopted in practise.

These results were not mere laboratory experiments. The process was in regular operation for many months, turning out several hundred pounds of electrotype shells every day, and the number of shells found defective was surprisingly small. The secret was simple enough; it was merely a question of ***keeping the electrolyte under control***, so as to maintain it in substantially the same chemical, electrical and physical condition all the time. The amounts of copper sulphate and free acid in the electrolyte, the density, specific resistance, and temperature, of the electrolyte, were all maintained within certain limits; and the electrolyte was systematically agitated and circulated. The object in view was, of course, to put the electrolyte in the best possible condition to meet the urgent demand for "ions" resulting from the high-current densities. If there is not enough copper in solution at the cathode to satisfy the "cation" requirements of the current, the deficiency will be made up by a partial deposit of hydrogen with the copper; and it is well known that a very small proportion of hydrogen is sufficient to alter the quality of the deposit. The great difficulty is to prevent the deposit at the cathode of other elements than copper. Hence, as a rule, high current-efficiency is a condition (though, perhaps, not the only condition) for a good deposit.

High current-densities (up to 300 amperes per sq. ft.) have been employed in more recent years in connection with processes for making copper-tubes and sheets by the electrolytic deposition of copper on rotating cylindrical cathodes.

In electrolytic copper refining, high current-density, though still possible, in theory, is excluded, in practise, for the good reason that "it would not pay." Aside from the increased amount and cost of electrical energy that would result from the use of higher current-densities, there are other important considerations which argue strongly in favor of low current-densities. The electrolyte is more complex and much more variable in chemical constitution by reason of the impurities contained in the anodes, and which eventually pass into the solution, or else form a part of the "slime." This slime contains the precious metals, gold and sliver, which are recovered through the process of refining. It is necessary to guard carefully against loss of precious metals by their being carried over to and deposited on the cathode, either electrolytically or mechanically. This means, practically, that the electrolyte must not be stirred violently; indeed, it can scarcely be stirred at all, to increase diffusion. The difficulties and the cost of maintaining the electrolyte at a high constant conductivity, either by raising the temperature, or by chemical treatment, and the difficulties incidental to circulation or agitation of the solution, are very much greater than in the case of an electrolyte serving for electro-deposition when using anodes of pure copper. Experience has shown that the advantages, such as increased output from a plant of given size, etc., do not offset the disadvantages and the increased cost.

There is also some misunderstanding in regard to the cost of the power required for depositing copper. Paradoxical as the statement may seem, it is possible, theoretically, to deposit any amount of copper with a given amount of electric power. A mathematical demonstration of this possibility was given by me some twenty-five years ago in a series of articles published in the *Electrical Engineer*. The electrochemical principles on which this interesting possibility depend were set forth by Dr. N. S. Keith, the founder and first secretary of this Institute, in the discussion of a paper on "Depositing Vats in Series," read by Mr. Slater, at the first meeting of the A. I. E. E. at Philadelphia, in October, 1884 (see Volume I of the A. I. E. E. TRANSACTIONS). When there is no polarization-effect produced at the anode or the cathode, in other words, when the thermo-chemical reaction (heat of formation) incidental to the dissolving of copper at the anode is exactly equal to that incidental to the deposit of copper at the cathode, as is the case when electrolysis takes place with a low current-density between plates of pure copper in an electrolyte of pure copper sulphate, all the "ions" then consisting of copper only, there is no consumption of energy except in overcoming resistance. In such a case it is possible to increase the total amount of copper deposited without increasing the total amount of electrical energy expended. Suppose that, in a given case, starting with a certain number of vats in series, we add a second series, exactly like the first one, in multiple. If the current-density in each series be made one-half what it was in the first series, the total current passing through the two series in multiple will be the same as before, and the total amount of copper deposited, on the assumption of 100 per cent current efficiency, would be the same as before. The difference of potential between the anodes and cathodes in each vat will be reduced to one-half, because it only depends on resistance-drop, in the absence of polarization. If we still wish to retain the same working power in the circuit, we may add as many cells again in series to each of the series. We will then have four times the number of vats and four times the number of cathodes on which copper is being deposited with one-half the current density, and, consequently, one-half the rate of deposit that was obtained when one set of vats alone was in use. With four times the number of plates receiving a deposit at one-half the original rate, the total output in copper will be doubled. By increasing the number of series connected in multiple to four, the number of vats in each series could also be increased to four times the original number. The current density for the same total current and energy would be one-quarter what it was originally, but with sixteen times the number of vats and plates in use, the total amount of copper deposited with the same electric power, would be four times what it was before. It is seen that the number of vats, and, consequently, the size and cost of plant necessary to treat such a large amount of copper, would

increase in geometrical ratio as compared with the increase in output, and it is obvious that such a plan would not be economical. The saving in cost of power which might be effected by reducing the current-density to a very low value in a plant arranged as just mentioned, would come far short of offsetting the additional fixed charges and operating expenses of the greatly enlarged plant necessary, to say nothing of the loss of interest resulting from the greatly increased total amount of copper that would be under treatment at the refinery. Refining copper, being a commercial proposition as well as an electrochemical and mechanical problem, must be carried on under conditions which are compatible with the highest economy and which give the most profit. It is found in practise that the best results are obtained when the current-density ranges between 15 and 50 amperes. The exact current-density corresponding to the best financial result will naturally vary somewhat with the locality, design, and operating conditions of the particular refinery.

Lawrence Addicks: The higher the current density the more rapid must be the circulation in order to keep sufficient copper close to the cathode, which is the secret of good deposits. We are limited in that by the silver and gold losses, as the contents of the anode are left as insoluble slime in the tank, and we cannot afford to stir that up and foul the cathode. That is the commercial point which limits us.

I think a 1500-kw. turbine will use 17 lb. of steam per kw-hr. on the same basis on which I have shown the curves of the reciprocating engine. Take the triple-expansion engine at 15 lb., and we have a difference of 2 lb. of steam per kw-hr., which, at 15 cents per 1000 lb. is $39.42 a year, which is $2.60 per kw. Without disputing 18 per cent, that Mr. Longwell wants for depreciation, interest, etc., that allows us to spend $15 per kw. more on that installation, and right on this question of steam consumption, the reciprocating engine for that size unit certainly holds its own.

Mr. Newbury, on the other hand, says that simplicity is a great point, that the reciprocating engine is a complicated affair, and that we would much better have a steam turbine for the prime mover, an alternating-current generator, a transformer, a synchronous converter, and a booster. I think on that score also the reciprocating engine has something to be said for it.

C. H. Vom Baur: The oil engine has been used only to a slight extent in this country in electrochemical industries. Now that oil can be sold in the harbor of New York for less than three cents a gallon, 2.83 cents, actually in lots of 80,000 gallons, and in view of the high load factor in this work, the subject of the oil engine has again come to our attention. These engines will make power for 0.45 of a cent per kw-hr., taking interest and depreciation at ten per cent, and figuring in all the taxes and insurance, including liability insurance. There is so much of this heavy oil on the market, that contracts are made for a number of years.

These oil engines have been made in Europe in sizes as large as 2000 h.p. to a cylinder, so with the average size plant in which engines are used in this electrochemical industry, and with the average size unit, all the conditions can easily be met with the oil engine and with the oil that is now on the market.

Lawrence Addicks: There seems to be no question that it is possible to do better with the gas engine than the best that could be done in the case of steam. I looked at one of the oil engine installations in this country recently, I think it was of 400 or 500 h.p. capacity. The only difficulty with it was that it was subject to heart failure, and when it had one of these strokes and was shut down, there was considerable difficulty in getting it started. I think this engine is about two years old, and it has not shown the reliability that we feel is necessary in electrolytic work.

H. E. Longwell: As I understand it, the object of the meeting tonight is to consider what is, and what is not, a suitable prime mover for electrolytic plants; and when I say I do not think the gas engine is most desirable for the specified operating conditions, I do not want any one to get the idea that I do not think the gas engine has its uses. Neither do I want you to get the idea that I do not think the low-pressure steam turbine has its legitimate field of usefulness.

I have discussed the several types of power plant solely with reference to the operating conditions as I understand them, and I have endeavored to do it impartially and dispassionately. I also wish to assure you that my advocacy of the complete expansion turbine for this service, is entirely disinterested, and is based only on what in my estimation are sound principles of commercial engineering.

F. D. Newbury: Some criticism has been aimed at what I, in writing the paper, considered the least important part of the paper—the waterwheel-driven plant. The steam-driven plant is, of course, the one in which the copper refiners in the vicinity of New York are mainly interested.

In connection with the criticism of the size of waterwheel plant considered, it was not brought out in the paper as probably it should have been, that waterwheel plants are used mainly in the aluminum industry where large amounts of power are required, and for that reason a large plant was purposely selected. Experience has shown that in such plants the apparently more complicated power plant consisting of two or three links is in reality simpler, more reliable, more efficient, and less costly to maintain, than the installations consisting simply of the waterwheel and generator. With plants of 1000 kw. or 1500 kw. or even 2000 kw., I agree that the alternating-current generator and synchronous converter cannot compete with the direct-connected generator, if the plant can be located near the place of utilization of the current. In such circumstances, the distance of transmission is the only thing that would dictate the use of the alternating current-direct current system.

The possible difference between calculated and actual efficiencies was mentioned. The efficiencies of the various classes of apparatus given in this paper represent actual operating efficiencies, liberal allowance having been made for all losses.

Several of the speakers questioned my consistency in emphasizing the necessity of simplicity and, at the same time, advocating a plant involving the alternating-current generator, synchronous converter, and in some cases transformers and the synchronous booster. This position is entirely consistent and I believe Mr. J. B. Herreshoff will bear me out when I say that with the long experience he has had with most of the types of apparatus discussed, the one piece of apparatus he has had the least trouble with has been the synchronous converter. Obviously an alternating-current generator is more reliable, more efficient, than even a low-speed direct-current generator.

Mr. Herreshoff spoke of the possibility of obtaining to a certain extent voltage regulation with two synchronous converters supplied from one alternating-current generator by variation in power factor. What he said is perfectly true, but if that method is contemplated, it must be taken into consideration by the machine designer and properly allowed for, because a slight difference in power factor will mean a very considerable increase in local heating, and unless the converter is designed for that condition, it may cause a burn-out near the tap coil.

F. W. Harris (by letter): One very real advantage of the a-c. generator-sychronous converter plant over the d-c. generator plant lies in the fact that interchange of power with other stations is then possible. There is now little or no market for 250-volt d-c. current even in the cities and in the neighborhood of electrolytic plants there is none. The sale of excess d-c. power is therefore not practicable. On the other hand, there is a ready market for excess a-c. current at any standard frequency, and in an emergency, additional power can often be bought. There are certain seasons when power commands a premium and the fact that the power produced is a marketable commodity is an important one.

DISCUSSION ON "PROTECTIVE REACTANCES IN LARGE POWER STATIONS" (LYMAN, ROSSMAN AND PERRY), NEW YORK, FEBRUARY 25, 1914. (SEE PROCEEDINGS FOR FEBRUARY, 1914.)

(Subject to final revision for the Transactions.)

Philip Torchio: The authors have assumed that the generators have 10 per cent internal reactance, and some of the curves have been figured on that percentage. Although there may be modern machines that are being designed with the object of high internal reactance in view which have an internal reactance as high as stated, the great majority, or practically all of the machines in central stations at the present time, have internal reactances considerably smaller than 10 per cent. On 25-cycle machines the internal reactance will be 5 per cent or less. In such cases if you had assumed 5 per cent internal generator reactance, the figures and curves presented would have been considerably different and would have shown that there is little gain in installing bus reactances in excess of 12 to 15 per cent.

This large amount of reactance in bus sections is somewhat of an objection in most of the conditions where you have the feeders radiating from the different sections of busbars into substations and being multiplied in the substations, since these parallel feeders form a shunt to the reactance. If you have three sections of busbars divided by 20 per cent reactances, and feeders from these buses paralleled on substation buses, if you have trouble on one section, the protection that you get from this 20 per cent reactance is minimized by the impedance of the shunting of these feeders, and the effectiveness of these high reactances will be reduced to 12 to 15 per cent.

The authors point out the difficulties of having these reactances too high on account of having a phase displacement across the reactance which is shunted by feeder circuits and causing currents to flow through these by-paths. I do not think the paper covers fully the size of the reactances required, as they consider the bus reactances capable of carrying full-load current of one generator only, and the per cent rating is made on that basis; at least, that has been the practise followed by a number of engineers. I think it is a mistake to put in a reactance in the busbar that has less current-carrying capacity than the capacity of the switch which you put in for that connection. That is, if you put in a 1200-ampere switch to connect the busbars, the reactance which is in series with the switch should have a continuous carrying capacity of 1200 amperes.

I think the two points I make would tend to bring about a rather small reactance per section, that is, the per cent reactance, rated in the function of the carrying capacity to the switch, which I imagine usually is determined by the amount of maximum power you expect to transmit on that line from one section to another.

I regret that the paper does not cover the field of feeder reactances as fully as the busbar reactance, although it has been mentioned to some extent. It would have been quite an addition to have a complete treatment of the feeder reactance, which is, I think, one of the greatest mediums for securing protection of our high-tension systems.

W. S. Moody: The principal requirement of such reactance is that it shall be extremely safe and substantial. It is put in to protect at times of extreme trouble, and unless it is absolutely able to handle trouble within itself at such times, then perhaps it had better not be there at all. The heavy forces that have to be taken care of in the magnetic strains and the tremendous amount of power that has to be absorbed momentarily, all require the greatest rigidity and the greatest simplicity, and unusual factors of safety in every respect, in such a device.

With reference to the use of reactances, rather than the devices themselves, it seems to me there are two broad considerations that we want to remember. One is that all power these days is distributed on a constant-potential system. Consequently, an amount of reactance that interferes appreciably with maintenance of constant potential is prohibitive, but, on the other hand, we cannot have too small an increase of current at times of trouble and short circuits. Consequently, the amount of reactance and the location of the reactance, so long as they do not interfere with the maintenance of constant potential, cannot be used too freely, because even if the apparatus is quite capable of standing short circuits the operation of the system is that much less disturbed, to the extent to which the current at the time of trouble can be limited. So, outside of the financial consideration of the cost of the reactance, too much reactance cannot be introduced, in the sectionalizing of a system, so long as the maintenance of approximately constant potential is not interfered with.

Henry G. Stott: This is a subject which has been brought to our notice very strongly in connection with the redesigning of one of our plants, and also in connection with the introduction of large turbo units having a normal capacity of 30,000 kw. each. We went at the problem as from the point of view of trying to protect the generator from the cables, and to protect the generators from one another, and we ended up by trying to protect cables from the generators. The problem, therefore, was entirely transposed. The generator is pretty well able to take care of itself, but the instantaneous currents, which are reached through the normal action of having a number of these machines (we used five in our calculations) in multiple on the busbars, feeding out to a number of substations, with five and seven feeders in parallel, rise to such enormous values, going up to about 60,000 or 70,000 amperes at 11,000 volts, that we immediately began to foresee trouble due to the repulsion and attraction between phases. The

calculations showed, with three-conductor No. 000 feeder, subject to short circuit of 60,000 amperes, that the dynamic repulsion between conductors per running foot (30.5 cm.) was over one ton. That was one phase of the problem which rather startled us, but we were even more startled by finding that the calculation showed very high temperatures would be reached before any oil switches so far made, could be opened. We assumed the oil switch could be opened in 12 cycles, on a 25-cycle system—it did not seem safe to assume it would go out faster, on average operation—and we found that in the period of 12 cycles, or less, the temperature rise on such a cable would be over 500 deg. cent.

These are the things which forced us into the use of reactances, and, of course, it is quite obvious that the insulation

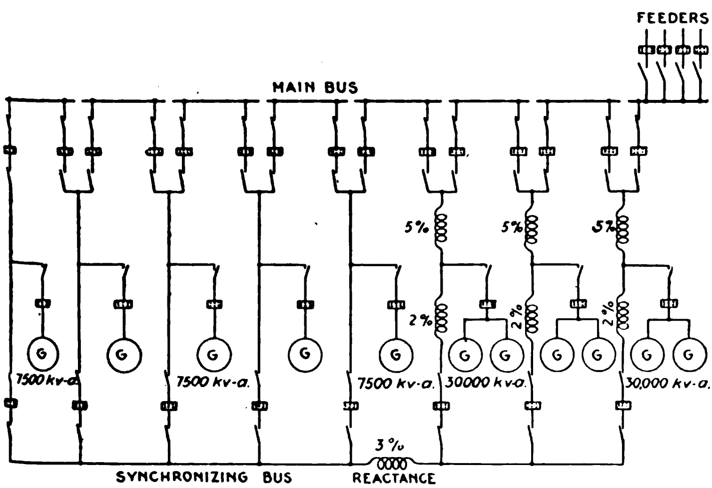


FIG. 1

of the cable would be partially destroyed by even one or two short circuits under these conditions.

We have adopted a scheme slightly different from any of those suggested in this paper, and it is shown clearly in Fig. 1, herewith. The bus normally is open, so each unit feeds out independently; but they are held in parallel through the reactances. As the load falls off, so that one of these units is sufficient to carry it, you close the bus junction switches and shut down the machine. The result is that there is no more reactance in one section than in another. The short-circuit currents in this arrangement work out very advantageously, also; the last calculation showed maximum short-circuit current of not more than 20,000 amperes, which is quite a contrast, compared to 60,000 amperes. We were forced into the use of reactances, not for the sake of protecting the machine, but to protect the

cable from the heating effect and the dynamic results of repulsion on the feeder.

The design of the reactance I think is quite important. It should be one which, as Mr, Moody said, is extremely substantial and practically indestructible from the heat point of view. That is a question yet to be settled, whether it will stand the shock and the high temperatures which will result on certain combinations. The ideal solution of the question we found was in use of individual reactances in the feeder, and we found also, as the result of that discovery, that we would have to build a separate plant to hold the reactances, and that did not seem to be quite feasible at this time, considering the present value of real estate. So the scheme shown is simply a compromise between bus reactance and individual reactance in each feeder, but I think there is no doubt that the ideal solution is an individual reactance in each feeder, and none in the station. However, in large cities that is obviously out of the question, where real estate and buildings are so expensive.

Paul M. Lincoln: There is one point, in regard to the use of reactance, which in a great many discussions is lost sight of, and that is the transient period. If we assume 10 per cent reactance, and 100 per cent voltage, the maximum instantaneous current which can flow through the circuit is not ten times full-load current, but twenty times. If you hit the wave in the right place you will get transient conditions which will gives twenty times full-load current. It rapidly goes down to ten times full-load current. If one takes account of transient conditions he gets twice as much current as he will under steady conditions.

Taking time along a horizonatal line, it is well known that during the transient period the voltage waves will become symmetrical, around a logarithmic curve, that is, asymtotic to the X axis, the greatest departure of the logarithmic curve from the X axis being just exactly the full voltage.

That is a condition which, unfortunately, most writers on this subject do not take into account. When, for instance, the authors of this report say so many times full-load current of one generator, we do not know whether they mean to take into account the transient condition or not, but if they do not consider the transient condition, it is easily seen that the worst condition may give a current as high as double the value which is named.

I believe that we all, after we have analyzed this problem, will take exactly the same attitude that Mr. Scott has taken. The intention at first invariably is to get something to protect the generators, because it was the generators which suffered in the early days. Now, we have gotten around the generator, know how to protect it, how to build a generator so that it is self-protective, and now the problem is to protect the service from the rush of current which comes out of the generator. It is now the service that needs the protection, and not the apparatus, and if

we bear that in mind in the study of this problem I believe it will throw a great deal of light on it.

V. Karapetoff: I was glad to hear Mr. Lincoln mention the transient period of short circuit, because I have felt for some time that we must not allow the generator to exert its full destructive action the very first instant of a short circuit, but must provide something within the generator to take care of this transient condition. The natural thought occurred to me to provide something in the exciting circuit, because the exciting circuit is smaller and lighter than the main circuit.

The most natural solution is to put additional reactance in the exciting circuit. Last week, I asked one of my assistants to make some tests, and while the tests were rather crude, because we had no oscillograph, and merely watched the instantaneous deflection of an ammeter, nevertheless, I think the results clearly show that reactance in the exciting circuit limits the first rush of current and is, therefore, useful. The size of this reactance is much smaller than that required in the main circuit, and what is more important, there is no objection to using iron in this reactance.

We used a small alternating machine in our experiments, and the normal value of the exciting circuit was 2.5 amperes. When the machine is short-circuited under certain conditions, and no reactance is put into the exciting circuit, the instantaneous exciting current (not the armature current) rises from 2.5 to 5 amperes. With sufficient reactance, the increase in the exciting current is only from 2.5 to 4 amperes. We also found a similar reduction in the armature current. The steady value of the short-circuit current, the value which occurs after a few instants was 75 amperes. Without reactance in the exciting circuit, the instantaneous deflection of the ammeter was as high as 180 amperes, instead of 75—the ammeter first goes to 180, and then goes back to 75, due to that transient condition. With the reactance in the exciting circuit, the deflection is ony 144 amperes, that is, it goes to 144, and goes back to 75.

It seems to me that here is a remedy which may be useful, not in replacing reactance in the sections of a-c. buses, but helping, at least, to reduce their size. In other words, I believe that it is not right to leave the generator to exert its full destructive action, but that provision must be made in the exciting circuit to limit this transient phenomenon by a sufficient reactance. If some kind of a constant-current regulator could be introduced in the exciting circuit, with a sufficiently quick action to prevent these sudden rises, then we could not possibly have these rises in the armature circuit, and consequently we would have less destructive action. In Dr. Steinmetz's book on "Electric Discharges, Waves and Impulses," there are several oscillograms given, showing what happens in the first instant of a short circuit on an alternator. The armature current rises instantly to a value much higher than its steady value, and the field current also goes

up, and is an oscillatory and pulsating current. We would not have these oscillations in the armature current, if we could prevent oscillations in the exciting current.

Harry R. Woodrow: I think Mr. Lincoln exaggerated a little the instantaneous rush of current on short circuit. The equation for this current in an inductive circuit is

$$i = \frac{E}{Z}\left\{\cos\left(\theta - \theta_0 - \theta_1\right) - \epsilon^{-\frac{r}{x}\theta}\right\}, \text{ where } \theta_1 = \operatorname{Tan}^{-1}\frac{r}{x}$$

and θ_0 is the angular phase of voltage at start of short circuit which must be at point of zero voltage to give maximum value of the transient term where X/r is large. Hence it requires π radius of electrical time for the transient term to reach its maximum value.

In the time π the transient term $\epsilon^{-\frac{r}{x}\theta}$ drops, so that the maximum peak is considerably below twice the normal. In addition to this, the generator voltage is materially reduced in the time π. From a number of tests on turbo-alternator short-circuits, we have found that the maximum transient peak will not exceed the normal peak by more than 50 to 60 per cent.

It is necessary to protect the generators, circuits, etc., at the time of this high initial peak which occurs in one-quarter to one-half a cycle, as any damage that is to be done is done at the time of maximum peak and hence no shunted resistance or reactance could be put in circuit quickly enough to do any good.

The last speaker recommended the insertion of reactances in the field circuits of generators. Punctures of generator field circuits now occur at times of generator short circuits due to the high voltage. By inserting an additional reactance in the field circuit to permit the field to be blown out within the first quarter of a cycle to reduce the current to one-half of its former value would require a reactance equal to the inductance of the field circuit and would reduce a voltage approximately as high as pulling the field circuit without discharge resistances.

Feeder reactance will give by far the greatest amount of protection against the trouble which occurs in feeder circuits, and by far the largest percentage of the troubles will occur in feeder circuits. In the tabulation the authors speak about the reactance limiting the current to 30 times the normal rated full-load current of one generator and they have something like 5000 kv-a. required for the best condition of reactances between adjacent generators. If reactances were installed on feeder circuits of the same system, two-thirds per cent reactance would be sufficient to limit the current to 30 times the full-load current of one generator, which would require about 1500 kv-a. in reactances or less than one-third the amount of bus reactance. This per cent kv-a. saving depends on the

size of feeder circuits, and is proportional to the ratio of size of generator to feeder units.

Cassius M. Davis: The paper under discussion considers an ideal case, namely, where a new generating station is to be put in, and arrangement can be made at the time of installation to lay out the system properly to get the maximum protection. There is one difficulty which usually confronts the engineer on a system which already is in operation and growing; that is, the system may have been laid out some years ago with no anticipation that it would grow to such large capacity; the feeders may be connected to the busbar in a more or less haphazard fashion, and in order thoroughly to protect the service at the various substations several feeders may be run in multiple to substations. As a consequence the system becomes so large that it is necessary to protect it by sectionalizing, and the difficulty arises in placing the reactances so as to get the greatest benefit. With a new system which has a large number of relatively small-capacity generators, or if it is a very large system, where there are a number of large generators, it can be laid out very advantageously along the lines which have been shown in this paper. A much more difficult proposition is the system which has been in operation for some time using small units, when it is decided to replace the small units with much larger ones. The feeders and the feeder switches have been designed and installed merely to carry the feeder current. Now, if the larger units are put in, the currents at time of short circuit are very much larger than previously, and therefore it is necessary either to equip the station with new switches or to protect the system in such a manner that the old switches will be able to take care of short circuits, or, as in the case Mr. Stott has brought out, it is a case of protecting the feeders.

A number of cases like this have recently come up. It has generally worked out that the best arrangement of reactances to give the best protection is a combination of generator and feeder reactances, rather than bus-sectionalizing reactances.

Mr. Stott's illustration (Fig. 1) is a combination of feeder reactances and what we may call synchronizing reactances. Each group of feeders is protected by a single reactance. Then the generator is connected without reactance, and each generator is maintained in synchronism with the others in the station by what may be termed a synchronizing reactance and synchronizing bus. It is purely a case of group feeder reactances, no generator reactance, and a section reactance primarily to keep the generators in synchronism. The station would operate just as well without the synchronizing reactances, the protection would be practically the same, but for reasons of convenient operation the synchronizing features becomes necessary.

Allen M. Rossman: Mr. Torchio remarked that our assumption of 10 per cent generator reactance was rather high.

We will admit that if we were working up the data for some of the older stations it might be high. But when we worked up these curves, we were planning a new 60-cycle station, and had no difficulty in getting guarantees of 10 per cent reactance in the generators, and so we based our curves on that value.

Mr. Torchio suggests selecting busbar reactances with an ampere rating the same as that of the oil switches in the bus-bars.

If you will refer to the diagrams in Fig. 8 of the paper you will find a close approximation to the required current rating. We have assumed one generator, two generators, three generators, etc., up to nine generators in operation, each carrying its full rated current. We have assumed that this current is fed out in equal amounts from each of the nine feeders or group feeders. You will find by glancing over the diagrams that in no case do we get higher than five-ninths of the full-load current of one generator through any reactance. This figure, with an allowance for unbalance of feeders, gives the proper current rating for the reactances as well as for the bus section switches.

Mr. Stott has stated that in installing generator reactances at an old station another building might be needed to accommodate them. The space required and the high cost are, I think, the chief objections to the extensive use of generator reactances. Reactances in the generator leads are in my opinion, best adapted for the protection of the generators themselves, but with the generators that we are buying these days it is not so necessary to provide additional reactances in their leads, because of their high inherent reactance and their improved mechanical construction.

Mr. Woodrow has commented on the question of transient effects, raised by Mr. Lincoln, and I will not say anything further on this subject. The method of deriving the curves, as shown in the appendix, considers only the Ix drop.

Mr. Davis has made some comments about stations which were designed some years ago, and on further growth required the addition of reactances. I might mention that not many of the large city stations built a few years ago were designed to deliver the amount of power we are calling on them to give today, and the application of reactances to these stations may be considered special cases. These older stations designed perhaps ten years ago, or even seven or eight years ago, have to give way to new stations, and it is the application of reactances to these very large stations that our paper is intended to cover.

Referring to Mr. Davis's question as to the rating of the reactances, the rating of the reactance is based on the current times the voltage. If we double the current we get double the voltage, because we have twice as many ampere-turns, and therefore we get four times the reactance, therefore the rating varies as the square of the current.

O. J. Ferguson (by letter): Last summer I had occasion to study the various results to be obtained by putting reactors of various capacities in buses and feeders, with straight and ring buses. Based upon 10 per cent inherent reactance of generators, my general conclusions were as outlined below. It will be seen that they agree in many particulars with those of the paper we are discussing.

1. Additional generator reactors are not necessary.
2. The most effective method of placing reactors is to distribute them in buses and in feeders.
3. Based upon one-half the normal output of a bus section a 25 per cent reactor is generally sufficient for the bus.
4. A 3 per cent to 5 per cent reactor is advised for feeders.
5. If generators with 10 per cent reactances are fed to buses through transformers having 6 per cent to 8 per cent reactance, the bus reactors may be of lower reactance.
6. It is feasible to install bus-reactors of impedance sufficient to sustain synchronous apparatus on bus sections adjacent to the one upon which the fault occurs.
7. Owing to the demands of light-load operation, switches to bridge the bus-reactors should be developed and made interlocking with the generator switches so that they cannot remain closed when the reactor is required.
8. The present method of rating a reactor is not wholly successful.

As regards the reactor rating, it is worthy of note that reactors to be placed in feeders or in generator leads present a very reasonable demand that they should be rated in terms of those units.

When bus reactors are used, they are frequently rated in terms of only a part of the normal capability of the adjacent bus section as, for example, upon the basis of only one of the two or three connected generators. This is only a "local" rating and may lead to confusion and to incorrect comparisons of data, etc.

It is my belief, that inasmuch as reactors are subject to installation under such indefinite conditions, they might well have, beside their specific or local rating a fundamental rating in terms of volts reactance per 100 amperes at normal frequency. This could be called the "60-cycle reactive constant" of the device.

Alex. E. Bauhan (by letter): The paper gives considerable attention to the subject of voltage differences existing in the various sections of a bus equipped with reactances. This voltage difference of course is ordinarily a very undesirable feature, but under certain operating conditions becomes a briefly desirable feature. For instance, consider a hydroelectric system consisting of a generating station and two transmission lines having widely differing voltage regulations. Now it is evident that if flat voltage is called for at the substations and no synchronous condensers are available, it becomes necessary to operate the two transmission lines separately at the generating station end, which is usually undesirable.

However, if the two systems are tied together through a set of reactance coils it becomes an easy matter, by properly adjusting the load and excitation, to regulate the voltage on one system independently of the other and yet keep them in parallel.

This scheme is now being used on a high-voltage transmission system under similar conditions to the above. The regulation of one of the lines is 10 per cent at a maximum load of about 65,000 kw., and that on the other line is about 2 per cent with a maximum load of about 4000 kw. The generators are of about 10,000 kw. each. It is desired to give constant voltage at both substations, and as it is necessary to parallel the two systems at various times during the day, to make full use of the generating capacity, the voltage disturbances were very objectionable. However, by making use of bus reactance, which has already been installed, it was possible to operate these stations in parallel at any time, each system getting its proper voltage regulation.

This is a point which may not be of particular value in city distribution work, but may be well to keep in mind in connection with the operation of more extended transmission systems.

DISCUSSION ON SUB-COMMITTEE REPORT ON "DISTRIBUTION OF ELECTRICAL ENERGY" (JUNKERSFELD, ETC.), NEW YORK, FEBRUARY 27, 1914. (SEE PROCEEDINGS FOR FEBRUARY, 1914.)

(Subject to final revision for the Transactions.)

H. L. Wallau: The keynote of Mr. Junkersfield's paper is "centralization." Lack of centralization means a partial or total duplication of land, buildings, equipment and labor. In the proportion that centralization is accomplished, duplication is eliminated and further advantages accrue: (1) increase in the capacity connected that may be served from given equipment, due to increased diversity; (2) reduced investment per kilowatt, due to the use of equipment of larger unit size, and (3) reduced operating expenses.

These benefits lower cost, and as a direct consequence, rates are reduced; and generally they also result in greater reliability of service. A reduction in rates is always followed by a healthy growth in load, and increased reliability of service means much in permanently holding customers.

Other things being equal, one kind of current at one voltage supplied to all consumers would make for minmum cost. This consummation, however devoutly to be wished for, will probably never be realized, as each kind of current supply furnished has a field of usefulness of its own. Improvements in apparatus, such as the 60-cycle converter, will tend to broaden the field of the various classes of service, but it is difficult to imagine the complete elimination of all but one class.

Total centralization up to and including the sub-station is feasible today. Beyond this point partial centralization must be our aim, and the nearer this can be made to approach unity, the more perfectly we, as engineers, are serving our fellow-men.

In Cleveland we have aimed to centralize as much as local conditions would permit. The transmission system to substations is radial, with two substations in tandem. One cable is installed as a reserve between the generating station and the first substation, and also one between the first and the second substation. Until recently the reserve cable was kept alive at the supply end and the switch at the receiving end was left open. We are at present installing reverse-power relays of the selective wattmeter type on the receiving end of the cables, and will hereafter operate all cables in parallel. Tests show these relays to be very effective, and remarkably free from the limitations mentioned by Mr. Merriam on page 288.

Our reserve capacity under the radial scheme varies from 100 per cent, where one cable is sufficient to carry the total load, to 25 per cent, where four cables are required.

In order to minimize investment, it has been the policy to install originally to the second substation in the tandem group, two 2000-kv-a. cables. When the load has increased beyond 2000 kv-a., a standard 4000-kv-a. cable is installed, and the

two original cables operated in parallel as one, through one oil switch at each end.

In the matter of different classes of service, when possible, both a-c. and d-c. conversion apparatus has been connected to one high-tension bus, reducing the transmission capacity required, because of diversity and improved power factor. This scheme is also followed, as far as practicable, by having one a-c. and one d-c. substation in tandem, reducing the investment in transmission between the generaing station and the first substation even more than in the case of two a-c. stations, due to the greater diversity.

Power factor has also been improved by the use of synchronous condensers in substations and on consumers' premises.

The diversified routing of transmission lines has been touched upon by Mr. Gear. This is advisable whenever the investment in subway will permit, but care must be exercised to have the distances approximately equal in order that excessive loads may not be carried by certain lines, and underloads by others.

In the matter of railway load, specific cables are furnished only from the power company's nearest substation to the railway company's substation. Centralization of these stations may come in the future, but the time is not yet ripe for this accomplishment.

General distribution is at 2200 volts, three-phase delta, with single-phase lighting mains radiating from the load center, and three-wire secondaries. The large number of trees in " the forest city " makes this system of distribution much more reliable than the four-wire system.

Tests recently made on weather-proof insulation show that after a small amount of weathering the dielectric strength is less than 2200 volts, but deterioration from then on is slow, the wire withstanding safely the Y voltage to ground Hence, the liability to electric shock is very much decreased, with the lower voltage.

Small scattered power demands are taken care o by lighting feeders equipped with regulators. Large power is carried on separate power circuits, generally not regulated. The duplication of circuits is not as great as might be supposed, as the factory lighting is carried on the same transformer installation as the power (balance coils being used); and in the manufacturing districts there is relatively little residential or store lighting, so that a No. 6 primary lighting main will often suffice.

Adjacent a-c. substations are, on the average, about 2 1/4 miles (3.6 km.) apart. This compares very favorably with the distances between similar stations in other cities using higher voltages and generally the same size of copper in their feeders.

The maximum 2200-volt load on these stations varies from 1000 to 6000 kw., depending on the district served.

The type of station now standardized is very economical in floor space. A two-story and basement building about 50 ft.

(15 m.) square is capable of distributing a load of 20,000 kw., of which 12,000 kw. may be distributed at 2200 volts and the rest to bulk customers at 11,000 volts. 1500-kw. transformer banks consisting of three 500-kw. self-cooled units, are used. I do not agree with Mr. Gear that, for substations of over 1000 kw., air or water-cooled units are necessarily most economical.

Centralization is further carried out by serving, whenever economically possible, customers exceeding 300 kw. in demand, from 11,000-volt distribution cables with a single voltage reduction at the customer's premises.

Mr. Goodwin has called attention to the equity of charging a lower rate for high power factor and a higher rate for low power factor. A contract has been in force in Cleveland for about two and a half years, which accomplishes this.

Philip Torchio: I would like to ask Mr. Merriam if he can give us some of his actual past experience and data on the effect of the three methods of increasing the rupturing capacity of oil switches, by the use of resistances, especially, and the other method that he referred to, by using the resistance in shunt with the breaker.

S. D. Sprong: I would like to inquire about the experience had with four-wire, three-phase primary distribution. In this system we have the elements of three single-phase distributing lines, and the fourth wire is necessary to maintain the stability of the system. What is the experience in every-day operation, as to the effect of interruptions and short circuits involving the fourth or center wire; as to the unbalanced pressure on the three single-phase systems; and also, in the case of an interruption to the fourth wire, how does that affect the relation of the phases and the circuit as a whole?

D. W. Roper: As far as the short circuits involving the neutral are concerned, they give no particular difficulty. The circuit breaker on that particular phase wire which is involved, opens, clears the short circuit, and the voltmeter compensators are adjusted so that they will maintain the proper pressure on the other two phases. There is a compensator on the neutral wire as well, so that the neutral drop is compensated independently of the drop on the phase wires.

On the question of the neutral opening near the station or some place so as to cause an unbalancing, I do not recall that we have ever had any case of that kind, that involved any great portion of the circuit. There have been cases occurring in the outlying portions of the circuit, which involved a few customers only, but in general the neutral of the feeder, near the station, is a large wire and is generally an underground cable.

On the question of troubles involving short circuits and overloads, we have recently been trying a little heavier setting of the relays, that is, we have been abandoning the idea that the relays protect from overloads. We set the relays so that

they protect from short circuits only, and find that we give very much improved service, without any offsetting disadvantages. We have by the use of the heavier setting cut out such a large proportion of the interruptions due to ordinary overloads or to no apparent cause, that we have a fixed rule that when the circuit breaker opens automatically in the substation twice or more in rapid succession, a patrolman is sent out to find the trouble, and in over seventy-five per cent of the cases he finds the trouble.

E. M. Hewlett: The question of relays has been considered so generally that one might think they were all alike. Many people seem to think that a relay, because it is a relay, will do whatever they desire it to do. Others, however, and particularly those who have made tests of relays on electrical systems, realize that to get proper results from a relay it is necessary to have a rational piece of work for the relay to do, to know the limits of its operation, what it is expected to accomplish, and besides, to not have extra circuits that conflict with the regular operation of the relay and upset the sequence of operation.

Then there are quite a number of systems which have been laid out with the expectation that relays would take care of all the troubles. Now, when the systems are too complicated, that is, have too many side paths, it is difficult to obtain proper protection. A more direct study of the problems involved, of the possible current flow in different directions, etc., should be made in connection with all these relay problems. I believe most of them can be taken care of, but in cases where this cannot be readily done, the system should be changed so that it becomes a practicable system. Some systems are actually impossible for continuous operation, on account of the connections, etc.

In reference to oil switch capacity, which Mr. Merriam brought out, an oil switch can be made for almost any duty, but it is, I think, rather, a question of the amount of energy which it is advisable to connect on any given system. There are magnetic strains in the system which will draw the conductors together and cause numerous troubles, and it depends on how much of a strain you wish to design your system for, how high a duty switch you desire, and how much money you put in the lines or systems. It seems as though 50,000-kw. sections would be about right, but you can run considerably above that with limiting reactances and with feeders so arranged that the energy flow under short-circuit conditions is reduced to a reasonable amount.

I wish to make a point about the so-called "safety first" movement. There seems to be a tendency in some quarters to go to considerable length to protect all circuits that are alive, irrespective of their location or the conditions under which they operate. Many people are of the opinion that *all* live wires should be covered and protected so that they can-

not be touched. Obviously this is going too far. While it is true that great attention should always be paid to the protection of human beings from injury, this idea should not be carried to extremes, and before making blanket decisions in this matter, a careful study of the conditions should be made.

In a manufacturing industry, for instance, there may be employed a thousand or more men to every thousand kilowatts of power used to operate the machinery, and practically none of the men conversant with the danger of touching live electric wires running to the various machines. Here the hazard is apt to be comparatively great, and it seems advisable to go to considerable lengths to safeguard against the hazard prevalent owing to the conditions.

In a central station, however, or wherever the live circuits are accessible only to those expert in their use, and fully cognizant of the danger of contact with them, it appears rather unnecessary to introduce many detail or minute measures of safety. In such an installation the ratio of men to kilowatts may be only one to a thousand, and besides, the chance of injury from accidental contact, in contrast to the manufacturing installation, very small. It thus seems, then, that where switchboards are under trained supervision and kept isolated from others, little further need be done to bring the degree of hazard much lower than it is now.

In reference to 2400-volt d-c. circuit breakers, etc., for railway work, the Butte and Anaconda line has been working quite a while now with a magnetic blow-out type of circuit breaker, but with the magnetic fields on both sides. The same kind of breaker has also been designed for a 3500-volt equipment for a French railway. Enough experimental work has been done on 5000 volts to show that the 5000-volt direct-current circuit breaker is also a practicable device.

H. R. Summerhayes: In Mr. Torchio's paper it is stated that the mains in the Edison three-wire system are always made the same size. I would like to know if experience has shown that on account of burn-outs, etc., it is actually necessary to make the neutral the same size as the outside wires. It is further brought out in Mr. Torchio's paper that, in spite of making the neutral the same size as the outside in the mains, the arrangement of the neutral in the feeders is such that the currents are balanced, and the total neutral copper is only 16.9 per cent as against 83 per cent for the outside wires.

In Mr. Gear's paper some mention is made of systems permitting the operation of cables in parallel to substations, and I would say that if all cables can be operated in pairs a balance relay system is available which will in general give very good protection. Of course, a large installation requires special study to see that all conditions are met. In reference to substations, it is probable that some saving could be made by automatic substations, in the case of the smaller stations.

Mention is also made in Mr. Gear's paper of the three-phase, four-wire secondary network. This is used to a greater extent abroad than in this country, but it appears to have certain advantages. I believe a study would show that it could be used to a greater extent here, to advantage.

Philip Torchio. Where full main neutrals are used they serve as well as feeder neutrals. Besides, the size of the neutral of the mains involves a question of securing a high degree of regulation. To explain: on the side where you have the heaviest load you have the heaviest drop, and, as the unbalanced load will come in on the neutral, if you make the neutral small you will exaggerate the drop on the loaded side. The Edison three-wire system of distribution has been designed with the greatest degree of liberality. While on a railroad system a poorer regulation may be permissible, our system requires very close regulation and, therefore, justifies greater liberality in the use of copper.

John B. Taylor: I ask Mr. Torchio just what he has in mind in referring to difficulties with the diametrical connection of synchronous converters—the diametrical as distinguished from the double delta connection? This diametrical connection has been in regular use in railway service for the last ten or twelve years, and while I cannot speak so well for the lighting field, I know that it has been on lighting converters for at least eight or nine years. The advantages of such a connection are, of course as obvious now as they were at the time of its introduction, and I do not see why there should be any special conditions in the lighting service that should delay for ten or twelve years the adoption of a connection which seems to possess such pronounced advantages over a connection that has been used largely as a matter of chance, I think, previous to that time.

I should like to hear from Mr. Merriam regarding what is, perhaps, a misstatement as to the function of the oil switch in interrupting a circuit. The switch is to interrupt the circuit and the idea is, in addition, to make a switch so that no absorption of energy by it will occur. Unfortunately, it seems to be true, with switches as they are constructed, that it is impossible to avoid dissipating a certain amount of energy in the switch itself, but I cannot see that there is anything inherent that calls for the dissipation of energy in the switch, nor why the switch cannot be so designed that the energy does not have to be dissipated there. A parallel case is when you have water in a pipe. You may have any quantity of energy stored in your reservoir, back of the point in the pipe where you wish to interrupt the flow and the mere closing of a valve does not necessarily absorb any considerable portion of the energy thus available, and I think, at least on paper, it should be possible to design a switch in which the energy absorbed or dissipated in the switch, at the moment of interruption, could be negligible. Practically, I do not wish to say that we are anywhere near doing that, but it seems to me there is a proper distinction there which should be kept in mind.

On the railway feeders, without going into details, it seems to me that the distribution network must meet two conditions. The first condition is that the railway trolleys, feeders, third rails, etc., must be more or less interconnected in order to work the conducting material at a fair economy, and also it must be possible to have them separated so that under operating conditions a short circuit at one point will not tie up things too extensively. This, of course, results in the various feeder systems, various devices for switching feeders, circuit breakers, etc. which must be placed along the line.

I see no specific mention in any of these papers of the use of the so-called "automatic sectionalizing switch"—a device which may be put on the line to tie together two feeders or sections of trolley wire or third rail, both of which are alive. These switching devices connect together two or more feeders, provided they are separately energized from the same or different substations, and in case of a short circuit, or in case of a desire to interrupt the power, merely by interrupting power supply to both feeders, at the substation or at the power station, these disconnect themselves, at which time power can be restored on one without restoring it on the other. Of course, this scheme is not universally applicable, yet there are so many cases where it would effect such marked saving in copper that it would seem to merit more specific mention.

I want to raise a question in connection with what Mr. Murray has to say about the single-phase distribution. The principal point he mentions is the one-wire single-phase railway transmission system. If we can believe the evidence of our eyes in riding over the New Haven road, it is clear that a change in that distribution system has been made, or is in the process of making. I trust Mr. Murray may have something to add on this point to reconcile the discrepancy between what is done, or done in part, on the representative single-phase road, and what he states is the desirable way of doing it.

Mr. Lincoln, it seems to me, has missed the real reason for the series lighting system. I do not think that the desirability of throwing the switch on at the power house to turn on all the lights on the street is by any means the controlling reason which brought about the series system. The series system came about through the inherent characteristic of the carbon arc, the property which has been commonly called "negative resistance", which meant that it was necessary to have controlling devices to keep the current within a proper value, and it was a much more economical proposition to do this either by the design of the machine at one point, or other controlling means, at a central point, rather than by individual steadying means at the lamps. Also we should remember that the arc light started as a d-c. instead of an a-c. system, so that it would have been out of the question to distribute at low voltage with an economical amount of copper, and out of the question to distribute at high voltage without

inserting the necessary transforming devices for individual lamps. So far as the d-c. arc is concerned, these conditions seem still to control.

The point I want to make is that the series system came in for good and sufficient reasons, which are other than the desirability of turning lights on and off at one time.

At the present time, with the ability to run tungsten lamps of high candle power on alternating-current circuits quite as well as on direct-current circuits, it looks as if the separate series circuit with the separate cables or ducts from the generating station had little excuse for continuing as the only street lighting system.

E. W. Trafford: With reference to Mr. Lincoln's paper on arc lighting distribution, I want to say that a few years ago, in a station which now has about 2000 arc lights, I saw that we were filling our streets with a large number of small wires, and recognized the desirability of reducing the number of wires and using those of larger size. A great many years ago a system was devised which made use of constant-current distributing transformers. I have used that system for the past three years with considerable success, with circuits of 200 arc lights, using 30 amperes constant current at 4000 volts.

Instead of distributing current single-phase a three-phase star connection with series transformers in each leg may be used, in which case, with the same current and voltage, the circuit would be of 250 kv-a. capacity. Such a system has many advantages with both overhead and underground distribution, perhaps more noticeably for underground distribution, where a few cables of convenient size can be placed in the ducts in place of the multiplicity of small cables usually employed. The system also offers great advantages in a mixed underground and overhead distribution. It is easy with this system to install a transformer and drop underground at any point and operate a separate series circuit of the desired voltage and current.

Instead of using constant-current regulators or transformers as they have heretofore been used, they may be employed merely as regulators in connection with ordinary static transformers. With a number of transformers on a given line it is improbable that all of the secondary circuit would open at one time and consequently the same percentage of regulator capacity is not necessary. By this means the power factor of the system can be very much improved.

In the station the substitution of a few devices of moderate capacity in place of the multiplicity of small apparatus results in a simplification of switchboards which is very apparent. In some cases, as in the one cited, the use of this system eliminates the necessity of a substation.

Objection to such a system in the past was based on the fact that transformer design was not as well understood as it is now, and that, upon the secondary circuit becoming open, a large rise

of potential would follow, causing burn-outs or establishing a dangerous condition upon the secondary circuit. But in these days of automatic devices it is very simple to arrange automatic switches which short-circuit the secondary, either upon a rise of potential occurring or upon the interruption of the secondary circuit. In the installation referred to, twenty-five transformers have been in service for about three years, without difficulty or the loss of a single transformer.

With this system it is possible to run a few well-insulated supply mains throughout the length of a city, and at convenient points install transformers operating short series underground lines, at moderate voltage, thereby making it commercially practicable to furnish underground street lighting service even in communities of moderate size.

J. T. Kelly, Jr.: There are one or two things which we are doing in Baltimore, that, from the standpoint of the operating engineer, may be of interest to some of you gentlemen.

For the reason that has been mentioned several times, we are in the position of having to furnish as near absolutely perfect service as possible. One of the troubles which we have experienced is that of feeder interruptions. The induction motors, even though the feeder may be restored in a very short length of time, will drop out and we have some complaints from customers on that account. It has been thought that if the feeder could be restored to service quickly enough, that trouble could be obviated. Experiments have been carried on with an auxiliary relay of the wattmeter type which operates to close the feeder switches as soon as they open, and it has been found that, with reasonable certainty, the switches can be closed within seven-tenths of a second from the time they start to open, or, putting it another way, on 60-cycle service, well within 40 cycles, and that there will be practically no rush of current to the induction motors, no interruption to the service, and as far as the lighting is concerned, merely a very slight flickering. This was the idea of our Mr. F. E. Ricketts, who has carried through the experiments and reached the point where the system is about to be put in operation in one of the principal substations.

It will also have a very important use in outlying substations in the suburbs at which an operator is not ordinarily in attendance. I ought to say, in that connection, that these relays may be so set that they will close a circuit once, and if it drops out again, remain out, or they may be set to close the circuit two or three times, or as many times as you like, before remaining out.

The question of locating faults on underground cables is always a very troublesome one. It came to our attention, through our friends of the local telephone company a year or more ago, that certain of our frequency changers, operating at 2300-4000 volts, had such characteristics that there were present,

in the neutral, harmonics which caused a disturbance on the telephone lines. A study was made, and it was found that the thirteenth harmonic was present to that extent, and steps were taken to change the characteristics of these machines. The idea occurred to some one, however, that that might be made use of in the locating of underground cable faults, and it has been made use of. The method is to connect a machine having this characteristic in a marked degree to a spare bank of transformers, preferably of large capacity, and connect the faulty cable in series with the neutral between the machine and the transformer bank. If the cable is broken down between conductors, a dead short circuit two conductors may be used; if it is broken down to ground, one conductor and the lead sheath may be used. Since we are trying to get rid of that characteristic in our machines, it was necessary to rig up a small set, of about 5 kw. capacity, which we ordinarily use for that purpose with much success.

The method of finding the fault after the connection is made is by means of a small finding coil in series with a delicate telephone receiver. It is only necessary to go into the man-hole and hold the finding coil close to the cable. If you are between the station and the fault, the harmonic is present, and you readily hear the tone in the telephone receiver, which is a very different tone from the general tone of the system, and readily discernible. The moment you get beyond the fault, you fail to hear the tone.

John Murphy: I have read of such a scheme being employed in Berlin, and a friend told me that it was not necessary to enter the man-hole. The sound is detected walking along the street. I would like to ask Mr. Kelly if he has heard of that system or used it.

J. T. Kelly, Jr.: On our distribution feeders we have adopted the method of placing an expulsion type fuse between the main feeder and practically all the principal taps from the main line. These have the advantage of acting as disconnecting switches, if desired, as well as of clearing the main feeder of trouble, instantly, when trouble occurs on one branch.

Our company has spent considerable money to perfect a system, both in the overhead and underground portions of the a-c. territory, of tying in adjacent feeders through oil switches at as many points as possible, within reason. We use oil switches in every case, properly phased out beforehand, and in connection with this scheme we furnish each of our trouble men with a small pocket-size loose-leaf binder, carrying bulletins of various information, and many other things, including diagrams of the emergency connections of each feeder, so in case of trouble it is not necessary to get hold of some one who may be familiar with all these points, or may be familiar with the record of them. Each trouble man has in his pocket the specific direction which will enable him to restore service in the

shortest possible length of time. At frequent meetings the trouble men are coached and quizzed on these points to see that they are kept in mind.

There is another point in connection with that—the tying in of feeders on the outside may be considered in the light of a station switch of which the station operator has no knowledge. We have found it a very wise thing in every case to advise the station operators, in advance, of such and such a switch, so they may know what to expect, otherwise the performance of their instruments, regulators, etc., may be very misleading to them.

I notice the statement which was made in regard to the Commonwealth Edison Company, that in case of a short circuit on one phase the breaker on that phase will open and the other phases remain in operation. We have not been able to do that, with success, for the reason that we have a great deal of three-phase load on our distributing feeders, and we have found that, when we attempt to operate two phases of a four-wire feeder, the third wire being dead-grounded or short-circuited with the neutral, we blow the fuses on our three-phase banks of transformers and get into a good deal of trouble. Our breakers are therefore locked so that they operate together.

H. B. Gear: Answering Mr. Kelly's question, the difficulty mentioned is avoided in the Commonwealth Edison system by not connecting the neutral of three-phase installations to the neutral of the system. When this is done trouble on one phase cannot be communicated through the transformers to the other two phases. This has entirely remedied this sort of trouble, in Chicago.

Carl Schwartz: The distribution of electrical energy in a certain territory is a natural monopoly. Competition is bound to lead to a duplication of facilities, resulting in less density of load per unit and a less favorable diversity factor. This condition also suggests pooling existing facilities. Any wastefulness in this respect, as well as in the design or development of a distribution system, will ultimately fall upon the public, either the company's stockholders or the consumer, who will have to pay a higher price for the product. When it is further considered that the cost of power at the busbars of the power station is generally below the fixed charges, operating and maintenance expense for its distribution, it will be seen that the economics of distribution deserve careful attention.

The distribution system of one of the railroad companies in New York City was designed after a complete analysis of practically all possible combinations of feeder connections and distributions of substations in order to arrive at the most reliable and economical combination. The system can be briefly described as follows: Primary three-phase alternating current at 25 cycles is distributed from two power stations at 11,000 volts to nine substations located from about 3.8 to 8.6 miles (6.1 to 13 8 km.)

apart, delivering direct current at about 660 volts to the third rail. Seventeen high-tension lines connect the two power stations directly with the substations, the latter being interconnected by tie lines.

All substations are supplied by not less than two independent lines and are equipped with three or four synchronous converters of either 1000, 1500 or 2000 kw. capacity, and in some cases, where continuity of service is of prime importance, with storage batteries. The direct-current feeder system connects the substations to the third rail through circuit breakers under remote control from the substations. The third rail is sectionalized throughout by the circuit breaker connections, the breakers being installed in thirty-two separate buildings, located from about one-half to two and one-half miles (0.8 to 4 km.) apart throughout the electrified territory, which extends over a total distance of about 51 miles (82.2 km.). The fixed charges, operating and maintenance cost of this system, including storage batteries and third rail, are, with the cost of current at the power stations busbars, in the ratio of about 1.3 to 1, which shows that this distribution system for d-c. railroad operation is economically designed.

The engineering features of a distribution system are so closely related to the generating system and its location, and to the distribution and character of the load, that a determination of the distribution system alone, without due consideration of all other portions, will lead to erroneous results. One system may permit the generation of current more economically and with a greater degree of reliability than another. For instance, large quantities of electricity are produced and distributed under more favorable conditions in the form of three-phase current than in the form of direct current or single-phase alternating current. At the point of consumption alternating current may be acceptable under some conditions and not under others; for instance, dense city service for light and power practically demands the insurance of continuity of service by storage batteries.

The efficiency of the distribution system alone, from an investment, operating and maintenance standpoint is, therefore, not conclusive evidence of the wisdom of its selection, as its advantages may be counterbalanced by disadvantages incidental to the generation and application of the product. Hence, a proper comparison can only be made by analyzing from the coal pile to the point of delivery, whether the ultimate form of power be light, a motor pulley, the drawbars of a locomotive, or something else.

Appendix VII, on a-c. distribution for interurban and steam railroads, differs from the others in that it does not illustrate present practise, but offers the use of a single a-c. trolley wire as recommended practise. If this question was as simple and easy to answer as done in the paper, probably many of us would be thankful to Mr. Murray for the relief from a good deal of work.

The speaker does not wish to be understood as wanting to

detract in any way from the merits of the system Mr. Murray advocates, as it may, under certain conditions, produce results equally as good as or better than others. It is noted, however, that in drawing his conclusions Mr. Murray omits any reference to the matter of current supply and its complications, and apparently overlooks the fact that other forms of current on a trolley wire will likewise give satisfactory results, and even will avoid the necessity of carrying some equipment of the distribution system on the locomotives. If Mr. Murray should ask for a quotation for the delivery of single-phase power for railroad service, he would probably find that he has to pay an appreciably higher price than for three-phase current.

Mr. Blair refers to the important matter of electrolytic action. This question has been given very careful consideration by one of the railroad companies in New York City during the past few years. Exhaustive measurements of current and potentials have been made and recorded to determine the flow of current in steel structures, cable sheaths, pipes, etc.

A system of protection was developed which has made the structures likely to be affected as free from electrolytic action as possible, and it has been determined by laboratory tests and field investigation that the slight amount of current flowing is either too small for any appreciable effect or it has been so directed as to be inactive.

Insulated negative return feeders contribute to the prevention of destructive electrolytic action, yet, unless they are so connected as to produce fairly uniform pressures at the track, they do not bring about the desired result. To accomplish this, the loss in the feeders has to be balanced either by resistances or by boosters, and the cost of the insulated negative system thus increases rapidly with an increase in uniformity in pressure.

The subject requires considerable study from case to case to determine whether this system, or other methods like the drainage system, or a combination, is preferable. Structures can frequently be sufficiently protected by directing the flow of current so that they are negative to the running rail, and this method has, to a large extent, and successfully, been followed in the case to which I have referred.

DISCUSSION ON "THE PRESENT STATUS OF ALUMINUM-CELL LIGHTNING ARRESTERS" (CREIGHTON), NEW YORK, FEBRUARY 27, 1914. (SEE PROCEEDINGS FOR MAY, 1914.)

(Subject to final revision for the Transactions.)

V. Karapetoff: I would like to ask Dr. Creighton whether he has had any experience with the glass condensers and valves made in Switzerland and known there as the Moscicki condensers and Giles valves.

F. W. Peek, Jr.: It is some time since I have been actively connected with work on the aluminum lightning arrester. A number of years ago I had the good fortune to be able to make a study of lightning and the operation of the aluminum arrester on a practical line in Colorado. We had the co-operation of one of the operating companies in the experiments on this system which was high up in the mountains. It was a 17,000-volt network and a 50,000-volt main transmission, with a 50,000-volt idle line upon which to experiment. Various forms of lightning arresters had been tried by this company without success. It was practically impossible to continue operation during a storm. At this time the aluminum arrester was very new and we did not intend to make use of it as a practical protection; our idea was to make a study of lightning itself. However, in an attempt to improve operating conditions it was decided to install a few aluminum arresters. These arresters could not be obtained from the factory at that time. It was a very difficult country to get into. A sufficient number of aluminum cones was obtained, however; containing tanks were built in the mountains, and the electrolyte was compounded from chemicals bought at a local drug store. An arrester was thus built up and put into operation, and it did very good service. It was decided to install a few more. At a later period in the season these were obtained from the factory and were distributed to various substations. During the latter part of that season there were very severe storms and very little trouble. Many improvements have since been made in the arrester, notably in the electrolyte and in the addition of charging resistance.

The aluminum arrester is the only arrester at present that can take care of a condition of high-energy lightning discharges of moderately steep wave front or moderate frequency. This is often the only condition; generally the prevailing one that must be met. Good protection is thus obtained in the majority of cases with an occasional miss during the season. There are certain conditions, generally in the minority, but which occasionally on a few systems are the prevailing ones, which no arrester with a gap can, unaided, satisfactorily take care of. These conditions are:

1. Lightning impulses of exceedingly steep wave front and high voltage.
2. Impressed high frequency of a voltage insufficient to discharge the gap.

In condition (1), the dielectric breakdown time lag of the gap may prevent discharge of the arrester before discharge takes place at some weak point in the system.

In condition (2), discharge does not take place at the gap because the voltage is not high enough, but the oscillations may build up high voltage internally in an apparatus containing inductance and capacity.

Both conditions, (1) and (2)—which may be considered as more or less special—may be taken care of by the proper arrangement of resistance, inductance and capacity.

Good engineering requires as high system insulation as is economically possible, with the weak point at the lightning arrester.

L. C. Nicholson: Electrolytic lightning arresters are coming to be very widely used, and I think by this time they are recognized as the standard type of station arrester.

Frequently the question is asked—Are they efficient? Are they necessary? We operating people reply by saying, "Yes, they are necessary, if you think so," the result being that most of us are afraid to leave them off. As far as I am acquainted with the operating results of this type of arrester, there is seldom any apparatus damaged when protected by such an arrester, and I will also say that when the apparatus is not protected by such an arrester, there is very seldom any damage. So it appears that the arrester is all right. Except on extremely highly insulated transmission lines, damage to high-tension apparatus in the station by lightning is rare.

Usually lightning effects are so localized that the line has its own trouble and keeps it. I am acquainted with an installation which uses a pretty wide gap between the line conductor and earth, say 100 per cent over voltage, which discharges once a year, and which seems to be about all the protection that the station apparatus really needs, judging from the fact that no station apparatus has been punctured. I am acquainted with other stations which have electrolytic lightning arresters and which are not troubled by lightning and I am acquainted with some which have electrolytic lightning arresters and are troubled by lightning, so that it is very much of a question as to whether lightning will or will not do damage under certain conditions of station protection.

At least, the aluminum electrolytic lightning arresters have been developed to a point where there is no longer any danger of their exploding or giving any trouble on their own account if properly cared for, and the usual station attendant, with sufficient instructions, can properly care for the arresters and keep them in proper service. I feel sure that the addition of charging resistance has been of great benefit to the operation of this arrester.

The pity is that these arresters cannot extend their influence beyond half a mile from the station. In most cases the trouble is beyond that point.

C. O. Mailloux: Reference has been made to the character of the "front" of the wave which strikes a line or a portion of circuit protected by lightning arresters. It is known that the vertical front of a wave may be flattened out and sharpened to a point, so to speak, in passing through a reactance. It would seem therefore, as if one might expect that the character of the wave-front would depend somewhat upon the distance from the apparatus at which the lightning strikes the line. One might expect that the lightning striking the line very close to the lightning arresters would produce a current-wave having a squarer, straighter front, a more vertical one, than if it struck at some distance, owing to the difference in line-reactance. It may be that in most cases this would not make much difference. In any case, it should be possible to alter the wave-front, to some extent, by the introduction of artificial reactance.

C. P. Steinmetz: I wish to refer to only a few features. Setting aside failures of insulation due to weakness of poor design of bushings, insulators, etc., it occasionally happens that even a good lightning arrester fails to protect coils of transformers. The explanation o this is a feature which I have endeavored to make clear in my paper. These failures mean merely that when we speak of lightning we do not know the nature of the surge, and it is necessary to make such studies as will determine it—why at times the surges cause damage and other times they do not.

The aluminum arrester, with a gap in series, may protect against any surge which reaches the aluminum cells. Any disturbance of a voltage less that which will jump the gap and thus reach the aluminum cells naturally cannot be absorbed by the aluminum cells. Therefore, if we have a high-frequency oscillation of a voltage sufficiently low not to jump the spark gap and incidentally sufficiently low not to do any damage to the line, such a voltage may not be able to do harm to the insulation from line to ground, but when massing of the surge occurs in a few turns of reactance such as a single coil of a transformer, it may do very great damage because, while the apparatus is designed to stand the line voltage, it is not designed to stand half the line voltage across say one-hundredth or one-thirtieth of the circuit. The main trouble, due to high frequency, comes from the local massing of voltage across the reactance.

In speaking of high frequency we may refer to various different effects, and we also usually mean a thing which is not high frequency at all, is not even oscillation—it is steep wave front. A steep wave front, to some extent, causes the same trouble, namely the same massing of voltage, but n other respects it is very different. Some types o protective devices, like the multi-gap arrester, are very sensitive to high frequency, and will discharge high-frequency surges of voltages much less than the operating voltage, but they are not sensitive to steep wave front and may allow steady voltages of steep wave front to rise far above the circuit voltage without discharging.

Another illustration of this difference is given by the application of a condenser. Where there is very high frequency, a condenser shunted from line to ground may bypass or practically short-circuit the high frequency, but where there is a unidirectional wave the condenser will take a charge and thereafter offers no obstruction to the rise in voltage.

We must realize that electrostatic capacity is not a lightning-protective device—is not by itself a protection. A capacity from line to ground merely is a thing which will charge and store the energy. The storage is transient and the energy in the condenser must be returned to the circuit. Thus the condenser in the line will have no effect at all on steady voltage, or on low frequency. The favorable action the condenser can have is apparently to short-circuit disturbances of relatively high frequency.

Such disturbances, in my opinion, are rare, if they exist at all on transmission lines. For the reason that the capacity of the transmission line is so large, compared with the capacity which can economically be provided for in a condenser, any small condenser which can be shunted across the lines at the station would not be capable of appreciably short-circuiting the surge. Thus the high-voltage and the high-frequency disturbances of such volume and such current as can come in over the line are not cared for by any condenser of practicable size.

It is different when the surge comes from the other direction—that is, where the high-frequency disturbance comes from the station. In the transformer, as in the line, the circuits have distributed inductance and capacity, but in the transformers the inductance is very much greater, and the capacity very much less than in the line, and therefore the ratio of voltage to current of the disturbance is very much greater. In other words, capacity has an appreciable effect on a traveling wave, when the capacity is shunted around the high-potential windings of the transformer.

The value of capacity in protective devices lies in the fact that it is a barrier against the passage of current at machine frequency without being a barrier to the passage of surge currents which are inherently of high frequency. Under these conditions it is possible to use a resistance of low value in series with the condenser without absorbing any appreciable power at machine frequency. At high frequency, however, the power factor approaches unity and the maximum possible energy of the surges is absorbed. Thus it is seen that it is not the capacity in itself that is protective, as the voltage absorbed by the capacity at high frequency is negligible, but it is the capacity allowing a properly proportioned resistance to give protection by absorbing the energy of the wave.

This is the condition in the aluminum electrolytic cells, where there is a high equivalent resistance in series with the natural capacity of the cells.

The capacity of the aluminum cell gives a moderate power

factor at average machine frequency, but when there is applied a frequency of 100,000 cycles, the power factor of the aluminum cell is practically unity, that is to say, practically all the high-frequency current which goes through the cell is dissipated as energy and does not store itself as energy to be turned back into the circuit, as would be done by a simple capacity.

I believe that the action of the aluminum cell can best be represented by calling it a counter-electromotive-force device. It acts as a counter-electromotive-force shunt between circuit and ground after the voltage has reached a definite value. Up to this definite value, *i. e.*, discharge voltage of the spark gap, it is an open circuit, and beyond that voltage is a closed circuit. In the closed circuit condition it has about the same effect as if in a d-c. system you shunt a storage battery from the trolley wire to the ground. If you connect between the trolley wire and ground a 600-volt storage battery, then no lightning or any other disturbance will be able to raise the voltage of that trolley line appreciably above 600 volts because any attempt to raise the voltage would merely cause a discharge through the storage battery. The discharge rate depends on the internal resistance and voltage above the polarization of the storage battery; so it is in the aluminum cell, where the discharge rate depends on the voltage in excess of the polarization value and on the internal resistance of the cell, which, as we all know, is very low.

Now, as to the possible danger from the use of the aluminum cell, which has been especially discussed by those who have had very little practical experience with it—that is, the question whether it may produce high-frequency oscillation. One argument against the production of high frequency I have mentioned already the power factor of the aluminum cell is unity and it has no capacity effect at high frequency, but it gives a thoroughly damped circuit of a resistance which prevents oscillations. But from another view-point, the best comparison is that given by Professor Creighton—it is a safety valve from line to ground, of very high discharge rate.

We would not think of installing a high-pressure steam boiler without a safety valve, and still, many of us know that every once in a while you hear that a safety valve is really a source of danger, because if a steam boiler is superheated, and water is low, and just at the point where it is near blowing up, and if the safety valve operates, then the sudden shock of the safety valve opening may set off the explosion. But that is no reason for saying that it is unsafe to use safety valves and that all the steam boilers should be operated without them. It is exactly the same case with the aluminum cell or any protective device. If you protect the system against over-voltage, and if the energy back of the over-voltage is very large, it means that to relieve the over-voltage strain we have to provide a device with a high discharge rate, and the sudden coming into play of that high discharge rate, which is required to relieve the strain, means a sudden

shock to the system, and if you are near the breakdown point, that very shock may cause a breakdown.

But it has been said that it is not necessary to have a free discharge, and that a resistance may be inserted between line and ground—a critical discharge resistance which will gradually relieve the voltage without oscillations. That is very nice. By so doing the shock is removed only by keeping the excess voltage on the line and the apparatus for a considerable time, and for the time, in fact, that it takes to discharge, and since the disruptive strength depends on the time of applied voltage we wish to relieve, we must conclude that we are between two extremes. We have a condition of excessive voltage brought on by lightning or other disturbances. This voltage is dangerous, is certain to destroy apparatus and line if it stays long enough. We may gradually relieve, or we may suddenly relieve, but since the voltage is certain to destroy, the most effective way is to relieve it as quickly as we can, even if in the extreme case the very suddenness of the relief may accelerate the damage, which is, however, very improbable. I do not know of any instance where this has occurred, and I think the point raised in this connection is more theoretical than actual.

There is one point I want to mention about steepness of wave front The steepness of wave front depends on the distance of the place from the point where the wave originates. Theoretically, if you calculate transient phenomena of the line, you will find, by an equation, that the wave shape is so steady that the wave starting as a steep wave front retains its steep front all over the line. Practical experience shows that this is not so, and that is one of the various points where theory and calculation do not agree, or where, in our theory, we make an assumption which we find is not warranted—that is, we assume the effective resistance and effective conductance to be constant, independent of the frequency, while in reality every decrement increases with increase in frequency.

If you assume that the effective resistance of the line is a function of the frequency, increasing with increasing frequency, then you would find in the equations (if the equation did not come out so complicated) which so far have been beyond the mathematical skill brought to bear upon them, that the steepness of the wave form decreases with increasing distance traveled by the wave.

But while the equations have not yet been solved to give the values of the increase in resistance of the line, experimental evidence is available. There were some very interesting tests, for instance, made by Mr. Faccioli some years ago, on the wave produced by opening the high-tension switch in a 90,000-volt circuit. In that case, at and near the point of opening of the switch, the steepness of the wave front was such as to give, across a choke coil the inductance of which was equivalent to 50 feet of line, a potential difference of 30,000 volts, but the same size of coil on the same line at 20 miles distance,

gave no appreciable steepness of wave—that is to say, in the switching test there was no discharge on the spark-gap shunted around this small reactance. Within 20 miles of travel the wave front changed from an extremely steep one to a very flat one. This is the experimental evidence of the high-resistance offered by the copper line wire when the potential is suddenly applied.

E. E. F. Creighton: I feel that there is no need to say anything further about the Moscicki condenser, in answer to Dr. Karapetoff's question, as Dr. Steinmetz has already covered the subject.

I am glad that Mr. Nicholson has thrown a little spice into the controversy by speaking of the cases where apparatus was not damaged and the arresters were installed, and also cases where the apparatus was not damaged and the arresters were not installed. Each one of us speaks from his experience, especially his own personal experience, and Mr. Nicholson, I take it, is speaking from his. If I may be permitted, I would like to analyze some of the conditions under which he has been operating and then contrast them with some other experiences which have been gained on other transmission lines where the conditions are different.

On that particular system to which Mr. Nicholson referred there was, a few years ago, an almost insurmountable problem of keeping the lines operating during thunderstorms. I have the greatest admiration for the way in which Mr. Nicholson has attacked this problem and obtained a workable solution. The point of it was that the insulators on the line had not only less factor of safety than they needed,but they punctured, and where every insulator on the line is a lightning arrester it is quite true there is less need of lightning arresters in the station. Under these conditions the principal need of a lightning arrester in the station is where the lightning happens to strike in the neighborhood, and that, I think, corresponds to Mr. Nicholson's remark that it is too bad the lightning arresters cannot reach out more than a half-mile from the station. I should say that it is too bad the lightning is so terribly concentrated at points on the line. That represents to my mind the experience gained in that particular case.

On two other lines I know of, where the insulation of the lines was made for operation at 100,000 volts and the operating voltage was only 20,000 and 40,000 volts, the results were quite different. Since the factor of safety of the insulators was about 10, they were not functioning as lightning arresters or protectors for the apparatus, and consequently every lightning stroke that appeared on the line came with horrible impetus into the station. Switch bushings, transformer bushings, and other insulation that had withstood the conditions of other circuits, immediately began to break down from flash-over or by puncture. Lightning arresters of the best type were then required.

This is a condition that is gradually growing all over the country. Everywhere operators find that insulation on the line is an important factor, and are increasing the factor of safety in the line insulators. Personally, I would never use a factor less than three times normal potential, preferably still higher. The extra investment in insulators is worth while. This ultimately necessary practise will increase the need of lightning arresters.

The lightning arrester in itself is not a surge protector, but an over-potential protector. The gap setting is 25 per cent above normal operating voltage, and the arrester will operate as a surge protector only after the gap sparks and connects the aluminum cells directly to the line. I am somewhat disappointed that there has not been more adverse criticism, as our foreign friends are finding a great many things to say. I feel that any criticism or any failure of the aluminum arrester to protect the circuit can be explained by some weak local condition, or otherwise, the design of the arrester can be easily modified to meet new conditions. As Dr. Steinmetz has so well emphasized today, the great need at the present time is more definite information. A few years ago it was a very common thing to have bushings fail on transformers and switches, but today, due to the presence of the aluminum lightning arrester, these aults have almost entirely disappeared. Those that have not disappeared I hope to be able to give a reason for, at some not far distant time, as a result of the study of porcelain insulators at high frequencies. Porcelain insulators and bushings have a different strength at 60 cycles on which they are usually tested, from their strength at very high frequencies, such as 200,000 cycles per second—or its equivalent, expressed as steepness of wave front.

To be presented at the Pacific Coast Meeting of the American Institute of Electrical Engineers, Spokane, Wash., Sept. 9-11, 1914.

A DISTRIBUTION SYSTEM FOR POWER PURPOSES

BY F. D. NIMS

ABSTRACT OF PAPER

The paper describes the distribution system of the Western Canada Power Company, Limited, touching on the overhead and underground systems in general. It describes the advantages obtained by duplicating lines, both for eliminating outages and from a financial standpoint. Mention is made of the advantages obtained by using a steel-taped lead-armored cable placed directly in the ground, figures showing the exact cost of such an installation being given.

In laying out a distribution system for power purposes primarily, instead of a lighting or combined power and lighting load, several differences are encountered which lead to a much simpler and less expensive system. It is my purpose to describe the system of The Western Canada Power Company, Ltd., of Vancouver, B.C., giving some of these points in detail.

This company has its power house at Stave Falls, B.C., about 35 miles (56.3 km.) east of Vancouver, distributing power to Vancouver and the surrounding districts. The power house is located nearly in the center of a somewhat sparsely settled district containing several fairly large industries scattered throughout it at a maximum distance of 18 miles (28.9 km.) from the power house. A line leads south to the international boundary at Sumas, Wash., where it feeds a line of The Puget Sound Traction, Light and Power Company, of Bellingham, Wash., supplying 5000 kw. at 60,000 volts. This line is wood pole construction, single circuit, with pin type insulators, the conductor being a No. 0 equivalent steel core aluminum cable. The average span is 250 ft. (76.2 m.) and the maximum 970 ft. (295.6 m.) Arm pins are of the saddle type, made of one-in. (2.54-cm.) galvanized channel iron, no bolts going through the arm. The two legs of the pin are bolted together just above and below the arm. On angles, a small lag is screwed into the arm as a heel. This type of construction is shown in Fig. 1.

A steel-tower line, carrying two circuits of No. 0 hard-drawn

stranded copper with hemp center, runs from the power house for 33 miles (53.1 km.) to the receiving station at Ardley, located half way between the cities of Vancouver and New Westminster, and practically at the center of gravity of the industrial load. At Ardley, power at 60,000 volts is delivered to The British Columbia Electric Railway Company, Limited, which takes the current into Vancouver, where it parallels with that company's own system. Ardley station also steps the voltage from 60,000 down to 12,000, at which it is distributed to Vancouver, New Westminster and the surrounding district. The standard steel tower is shown in Fig. 2. On account of difficulty encountered from sleet and snow during the winter of 1912–13, the middle arm was extended, and Fig. 3 is a view of the same tower as it stands today.

All 12,000-volt lines are on wooden pole construction and carry, as far as possible, only one circuit to the pole, it being our belief that better service can be provided through making each circuit loop back to the transforming station by an entirely different route than to duplicate circuits on a single pole line; where more than one circuit is on a pole line they are generally considered and operated as a single unit. This method, by proper sectionalizing of the lines, reduces the chance of outage to a minimum, and when work is being done on the line, or stumps are being blasted, a short section can be isolated and killed so that linemen are absolutely protected from adjacent circuits; or if a piece of stump is blown into the line, no short circuit is occasioned which burns off the conductors.

Aside from the power house and main receiving station, no substations are used, as there are no voltage regulators or similar apparatus which require attention. Transformers are generally placed on pole racks and operate as ordinary distribution transformers. Figs. 4 and 5 give a typical example of such a rack. It carries three 50-kw. transformers stepping from 12,000 to 2300 volts. Switches are either oil-break, pole type, or a combination fuse and disconnecting switch mounted on the pole. The company has designed and builds in its shop such a switch, which answers the purpose exceedingly well and costs very little.

Patrolmen are stationed at important switching points so that these switches may be operated quickly in case of emergency. Fig. 6 shows an installation of three 333-kw. 12,000 to 2300-volt water-cooled transformers in the outskirts of the city of Vancouver. These transformers are indoor type so that

it was necessary to roof them over with galvanized sheeting. Water for cooling is taken from the city mains. The view is from the 2300-volt side, showing the disconnecting switches, outdoor type oil switches, cable terminals and cables with their pipe protection. A patrolman, who lives in the vicinity, visits the station periodically and adjusts the flow of water through the cooling coils. In some cases where a mill or factory has sufficient electrical apparatus of its own to warrant the employment of a skilled electrician, water-cooled transformers are installed in a small galvanized iron building. In short, the entire 12,000-volt system is handled in the same manner as a 2300-volt system, except that a circuit must be killed for a man to work on it.

Distribution in the cities of Vancouver and New Westminster is at 2300 volts by means of steel-taped and lead-armored cables laid directly in the ground, without conduit or other protection, except where crossing railway tracks or busy streets, where wood duct is laid to facilitate the pulling out or replacing of a cable without interruption to traffic. A trench is dug 30 in. (76.2 cm.) in depth, and of a width corresponding to the number of cables to be laid, (cables in place are from 4 to 6 in.—10 to 15 cm.—apart) the cable is reeled out and dropped directly into the trench. Joints are made by joint boxes, which cover the same character of joint that is made in the ordinary lead-covered cable, the space between the lead and the box being filled with ordinary bitumen, the box serving as a protection to the lead and also clamping the steel armor on both sides of the joint, providing electrical conductivity in the steel as well as mechanical strength in the cable as a whole. Fig. 7 shows five views of making a straight joint; the first showing the cable with one end ready for the joint, the armor having been stripped back, the lead cut back and the conductors separated. Fig. 7*a* shows the joint as made with copper sleeve connectors. Fig. 7*b* shows the joint with one end wiped to the lead sheath of the cable. Specially refined bitumen is poured through the holes in the lead sleeve after the ends are wiped, and the holes then capped with lead. Fig. 7*c* shows the straight joint box, itself, with the cover off, half full of bitumen, and Fig. 7*d* the completed joint. Fig. 8 shows the lower half of the joint box in the trench. Taps are made in a similar manner by means of a three-way box. At frequent intervals section boxes are placed in the line, these boxes being 18 in. (45.6 cm.) below ground level in a small manhole, or, more properly, handhole.

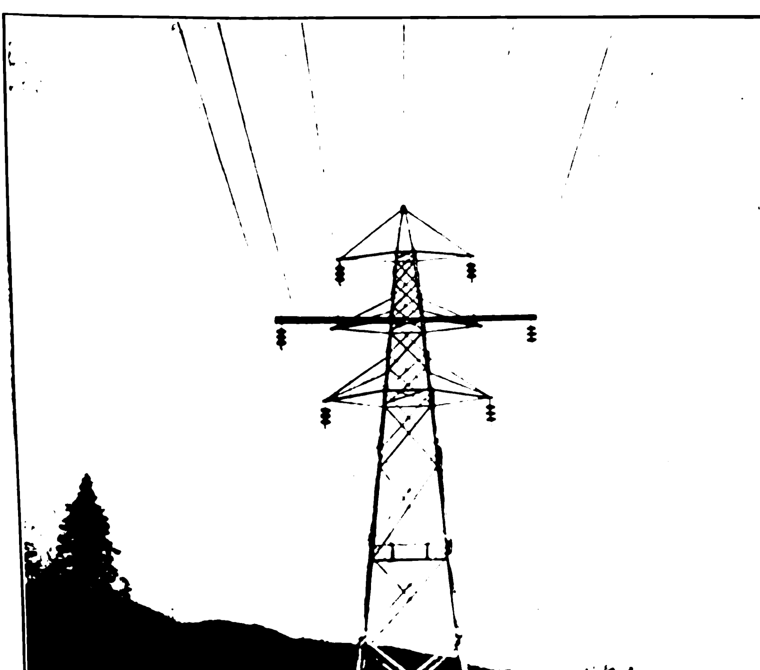
These holes have, as a bottom, a pad of concrete on which the box rests, the walls being circular and of cast iron; the entire hole being 26 in. (65 cm.) in diameter. The walls are flanged to take an ordinary cast manhole plate, which is used as a covering, these being flush with the street. Fig. 9 is a section box and hand hole with the steel form around it ready for pouring concrete. After pouring, the form is slipped off and the earth tamped in up to the concrete. The box has a bolted top which can easily be removed, and the copper links, which are set in porcelain compartments, can be taken out by means of wooden tongs. These boxes are used to isolate sections of cable when necessary to make new taps or work on the live conductors in any way, and also as interconnecting links between various cables, giving as a result several rings or loops. Fig. 10 shows a view of one of these boxes before placing in the handhole. The bolted cover is removed, showing the porcelain compartments and the copper links. The bell is of brass with a lead sleeve wiped in which fits over the lead sheath of the cable and is then wiped to it. After the conductors are connected and the lead joint wiped the bell is filled with refined bitumen, through the plug holes left for that purpose. The split armor clamp is also shown on the right side of the box.

Distribution transformers are placed either in vaults on the customers' premises or on poles, in which case the cable is carried to the top of the pole, where it terminates in an outdoor type terminal. Secondaries may be carried either back down the pole in the same kind of cable or run overhead to the building. Where cables run up the poles an additional protection is given by means of an iron pipe through which the cable runs. This pipe extends to a point about ten feet above the ground.

The question of cost on such an underground system must be taken up in each individual case, for it will vary a great deal with the quality of soil, cost of labor, probabilities of taps, extensions, etc., but it may be said, in general, that in places where it is not required to lay more than four cables in a trench, the steel tape cable, laid directly in the ground, will be found to be cheaper than any of the other systems. As a typical example of actual costs the following gives an idea; the figures being taken from a job carried out in Vancouver during 1911-1912.

[NIMS]

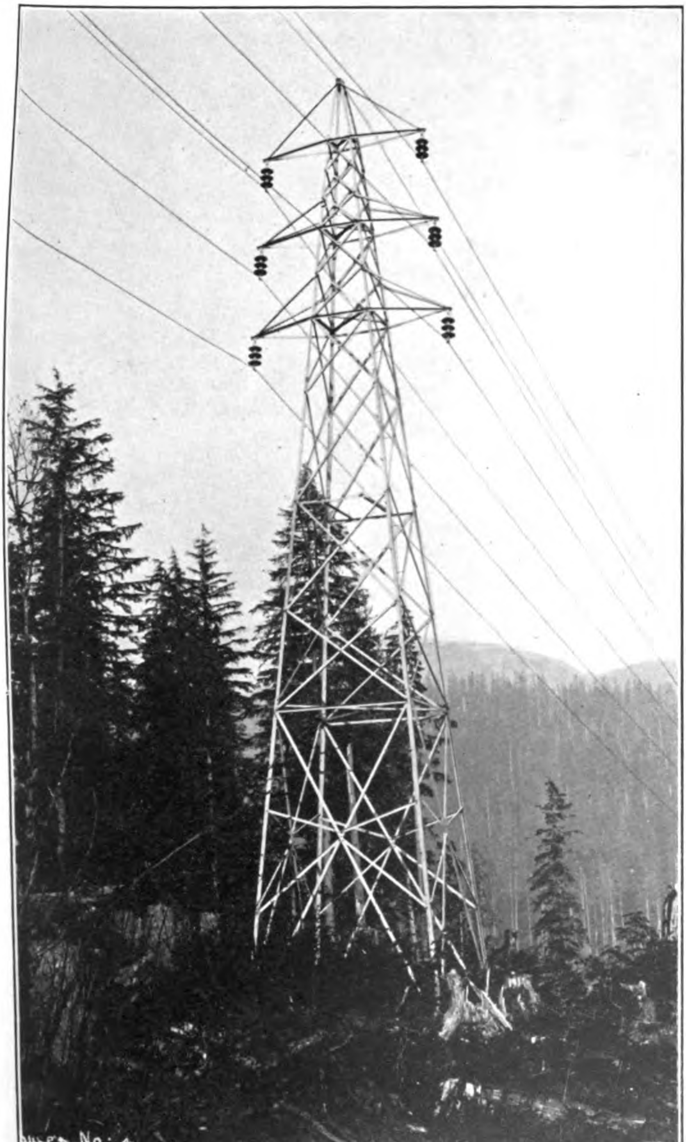
FIG. 1—POLE ON BELLINGHAM 60,000-VOLT LINE SHOWING SADDLE TYPE ARM PIN



[NIMS]

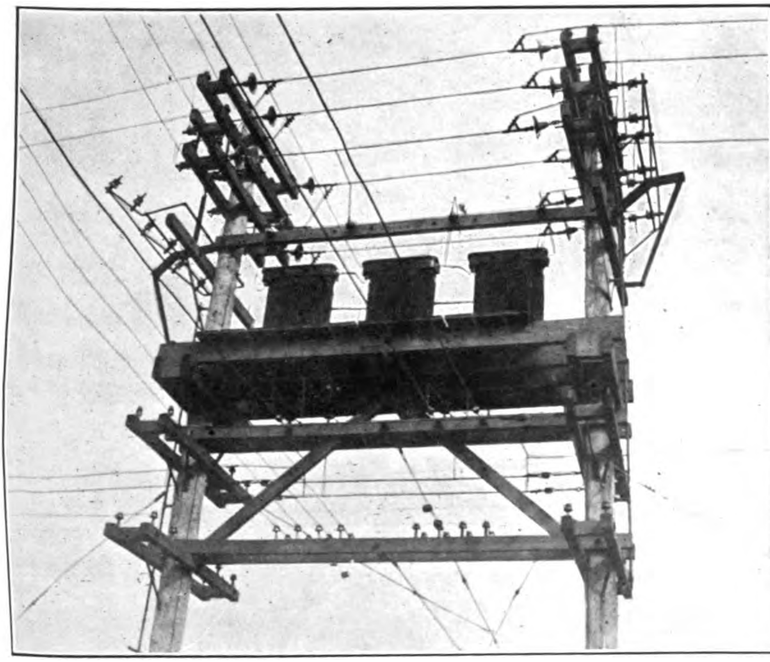
FIG. 3—STANDARD STEEL TOWER WITH CENTER ARM EXTENDED

PLATE LXI
A. I. E. E.
VOL. XXXIII, NO. 8



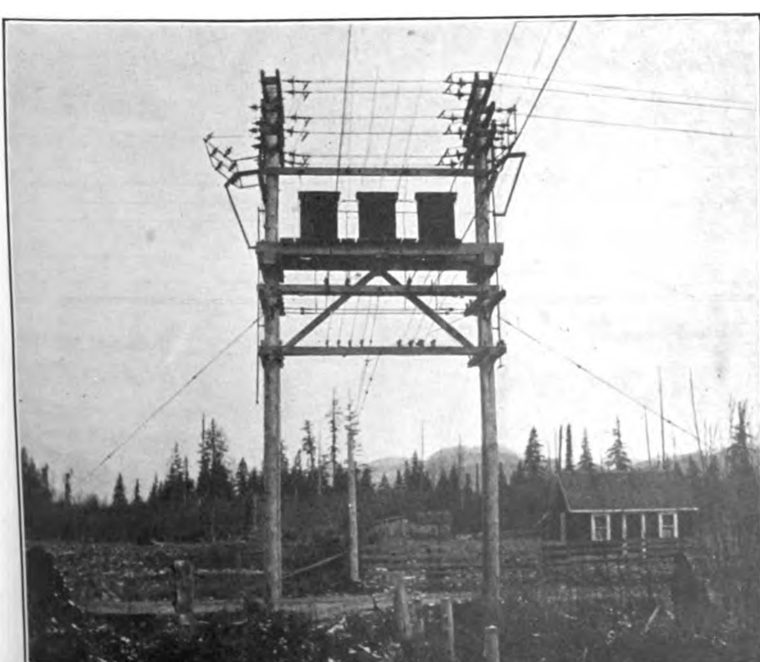
[NIMS]

FIG. 2—STANDARD STEEL TOWER WITH GROUND WIRE ON APEX



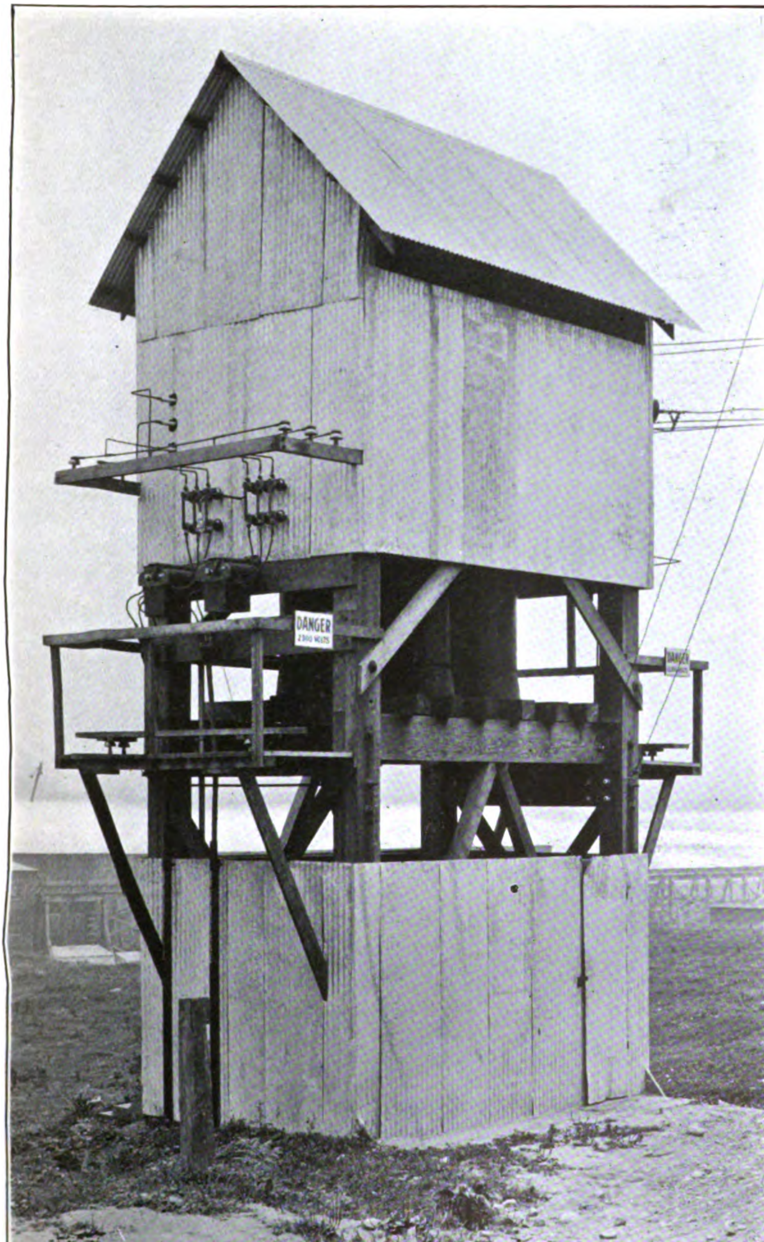
[NIMS]

FIG. 4—OPEN AIR RACK CARRYING THREE 50 KW. TRANSFORMERS 12,000—2300 VOLTS. OPERATED WITH POLE-TOP SWITCHES



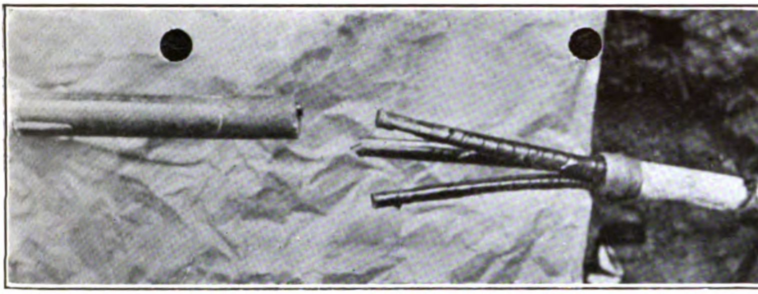
[NIMS]

FIG. 5—ANOTHER VIEW OF SAME RACK



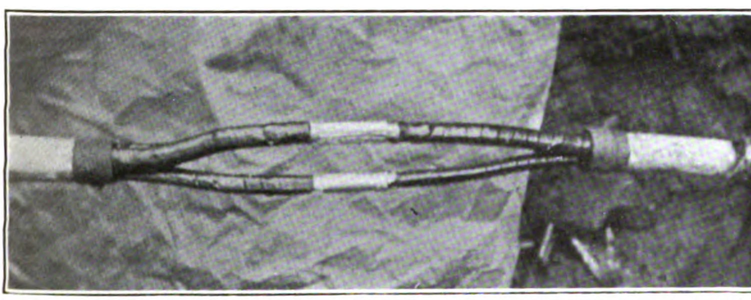
[NIMS]

FIG. 6—RACK CARRYING THREE 333-KW., 12,000—2300-VOLT WATER-COOLED INDOOR TYPE TRANSFORMERS



[NIMS]

FIG. 7—CABLES SHOWING ONE END READY FOR JOINT

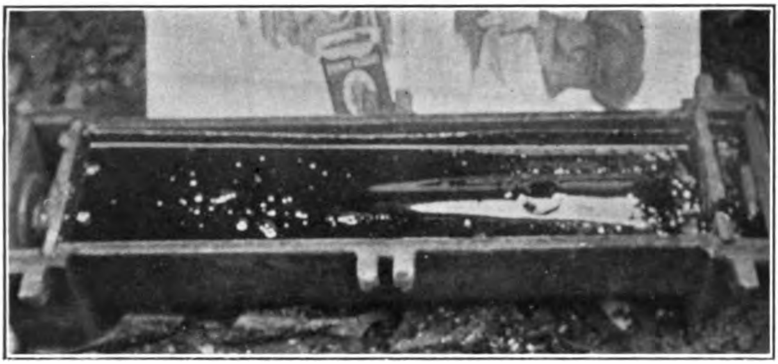


[NIMS]

FIG. 7A—JOINTS WITH CONNECTORS SOLDERED

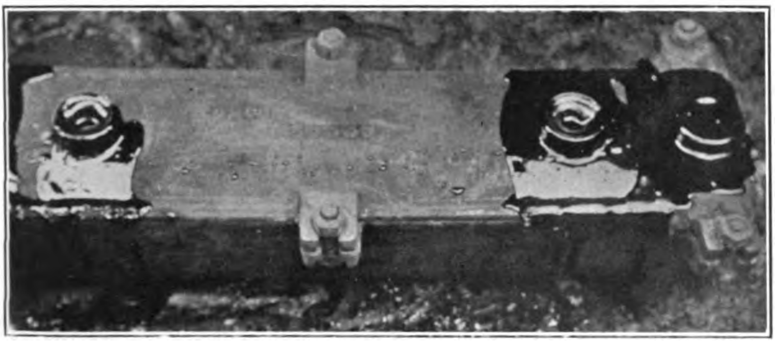
[NIMS]

FIG. 7B—JOINT WITH ONE END WIPED TO LEAD SHEATH OF CABLE



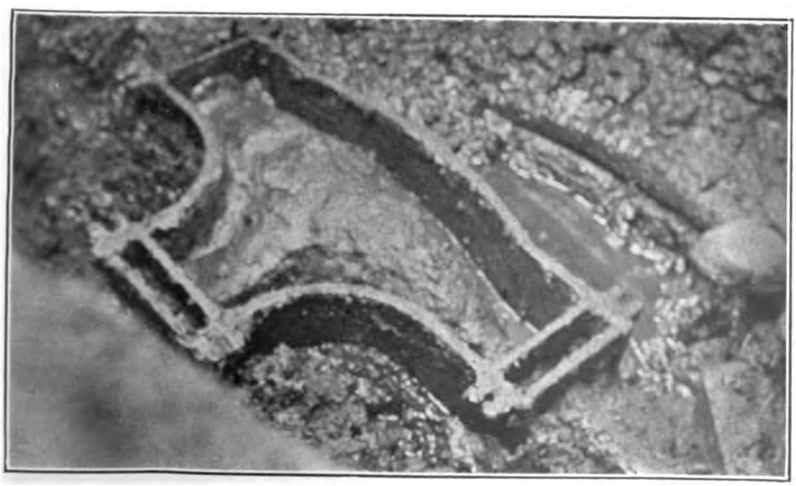
[NIMS]

FIG. 7C—STRAIGHT JOINT BOX, PARTLY FILLED WITH BITUMEN, READY FOR COVER



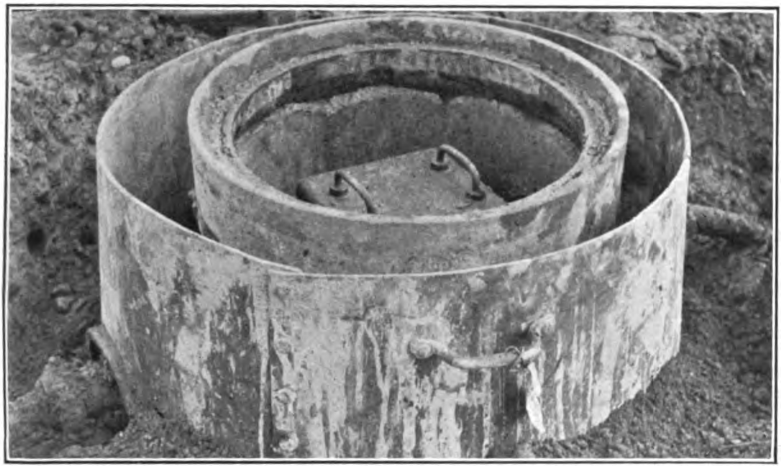
[NIMS]

FIG. 7D—JOINT COMPLETED



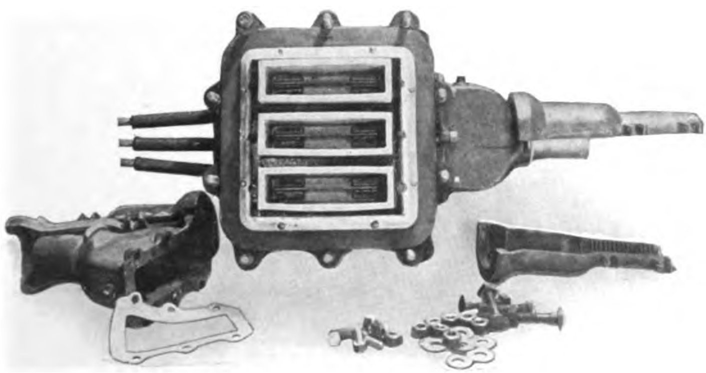
[NIMS]

FIG. 8—TEE JOINT HALF FULL OF BITUMEN



[NIMS]

FIG. 9—SECTION BOX IN PLACE AND OUTER FORM READY FOR POURING CONCRETE



[NIMS]

FIG. 10—SECTION BOX SHOWING PORCELAIN COMPARTMENTS AND COPPER LINKS

Size of Cable	Amount laid, feet	Cost per ft., cents	Total cost
No. 00	73,336.6	52.24 to 62.18	$44,319.26
2	560.0	42.5	238.00
6	1,071.3	29.6	317.10
TOTALS	74,964.9	60 cents average	$44,874.36

Pulling cable (including splicing straight joints) $0.04 per ft.				2,992.69
Trenching				
Unimproved streets	28,224.2 ft.	@ 0.50 cts. per lin. ft.	14,112.10	
Macadamized	13,207.9 "	@ 0.58 " " "	7,660.58	
Plank walk	1,190.2 "	@ 0.58 " " "	690.32	
Concrete walk	261.1 "	@ 0.95 " " "	248.04	
Wood block (con. base)	6,547.7 "	@ 0.95 " " "	6,220.32	
Brick Do.	203.0 "	@ 1.05 " " "	213.15	
Stone Do.	4,302.2 "	@ 1.10 " " "	4,732.42	
Bitulithic pavement	1,095.8 "	@ 1.15 " " "	1,260.17	
TOTALS	55,022.1	0.632 average		35,137.10
74 straight joint boxes	@ $14.90			1,102.60
15 Tees	@ 22.90			343.50
4 Outdoor terminals	@ 29.00			116.00
2 Inside terminals	@ 10.15			20.30
8 End bells	@			10.00
Labor on terminals & Joints (Not st. joints)				409.04
6 railway crossings (matl. 140.22 Labor 94.86)				235.08
96 street crossings (matl. 2440.18 Labor 1437.25)				3,877.43
Additional excavation for changes in grade				439.49
Moving building material etc.				294.70
15 section boxes, labor and material				2,250.00
TOTAL COST				$92,102.29

Cost per ft. of cable $1.23
Cost per mile of cable $6483.84
Feet of cable per ft. of trench 1.36
No overhead charges or engineering are included in the above.

Operating troubles have been few and far between, there having been, during two years' operation, but three cases. Two of these were caused by city workmen making sewer excavations taking the cable for the root of a stump and chopping into it with an axe or pick. On one of the pieces of cable so damaged we found the marks of 13 blows before the axe cut through to the conductor. The third case was a faulty joint at a section box which broke down the day after it was placed in service.

A complete card system is kept containing records of all cable locations, joints, etc., and we installed our own hubs in the streets as markers, the city hubs not being well defined.

This cable is practically a submarine cable, and in fact we have one length of 1500 ft. (457 m.) crossing the Pitt River, which has now been in service for two years without any trouble. The bottom on which it lies is fine silt or sand and there is a four-mile current caused by the tide. In another case it was necessary to cross a railway yard to furnish power to a pump located about 1000 ft. (304 m.) from the factory of the consumer,

the motor driving the pump to be controlled from the factory. As the expense of excavating for the laying of a cable would have been excessive and there was already a 12-in. (30.4-cm.) water main running from the pump to the factory, the cable was pulled in the pipe, the inlet and outlet of the cable being made through stuffing boxes. This has also proved very satisfactory.

The cable is composed of stranded conductors insulated with paper, the three conductors being insulated again with paper as a unit before the lead is put on. In most of the cable in this installation the conductors are sector-shaped, so that there are no spaces to be filled with jute or other material and a smaller over-all diameter is obtained, for a given size, than is possible with the round conductor, thus requiring less lead, steel and jute, and making a cable lighter in weight. The lead sheath is $\frac{1}{8}$ in. (3.1 mm.) thick and over this is wound jute yarn impregnated with tar. Outside of this jute are wound, in the same direction, two layers of mild steel tape 0.039 in. (1 mm.) in thickness and 1.5 in. (37 mm.) in width, so laid as to break joints. Over this tape is again wound yarn impregnated with tar. The over-all diameter of such a cable in three-core No. 00 for 4000 working voltage is about 1.75 in. (34.5 mm.).

One of the most important factors in the use of a cable buried directly in the ground, instead of being in conduit, is the ease with which heat can be radiated. Although the amount will vary somewhat with the character of the soil, it is safe to say that on this account an increase of approximately 15 per cent may be allowed in the current-carrying capacity over that in conduit. Exhaustive tests on this subject are now being carried out.

In regard to the life of a cable installation of this sort, nothing definite can be said as yet. The writer has personal knowledge of a large installation which has been in service in volcanic soil in the City of Mexico since 1900, and no perceptible deterioration has occurred, except where exposed to extreme electrolytic action, and in these cases it had a much longer life than lead cable in conduit in the same vicinity, due to the steel tape acting as a protection.

To be presented at the Pacific Coast Meeting of the American Institute of Electrical Engineers, Spokane, Wash., Sept. 9-11, 1914.

THE EFFECT OF DELTA AND STAR CONNECTIONS UPON TRANSFORMER WAVE FORMS

LESLIE F. CURTIS

ABSTRACT OF PAPER

The purpose of the paper is to show the distortions resulting from different symmetrical three-phase connections of generator and transformers without transmission line, as dependent upon the hysteresis cycle and the admittance of the transformers at no-load.

Tests were made with the oscillograph to show the no-load exciting current and voltage waves of three single-phase step-up transformers when the windings of the generator and both sides of the transformers were connected in all possible symmetrical delta and star relations.

Tests are divided into four groups, according to the connection of the generator. In all cases normal low-tension line voltage was held, but voltage and current measurements were considered less important than the recording of wave forms.

Oscillograms are given in each case and the relations between the flux, voltage, exciting current, and the hysteresis cycle are shown in two instances.

The author points out that the best voltage wave forms will, in general, be obtained with a star-connected generator and delta-star or star-delta connected transformers.

INTRODUCTION

IT is well known that the method of connecting three-phase transformers, or of single-phase transformers upon three-phase lines, influences the character of the potential and current waves, in that the type of connection limits the per cent of the harmonics of e.m.f. which may appear between lines and the per cent of the harmonics of current which may appear in any line. It is not the purpose of this paper to bring forth any new discoveries, but to present a series of wave forms, taken with the oscillograph, showing the wave distortions which are likely to occur in the different symmetrical three-phase connections.

Oscillograms of potential and exciting current were taken at no-load upon three single-phase, 10-kw., 1100-110-volt, 60-cycle step-up transformers when connected in all possible combinations of delta and star. The generator used was a 7.5-kw., 60-cycle machine, so arranged as to give the desired voltages

when connected either delta or star. It was thought that any distortions would be a maximum with the large transformers connected to the smaller generator at no-load.

Throughout all of the tests the line voltage was held at 110 when the transformers were connected in delta, and at 110 $\sqrt{3}$ when the transformers were connected in star.

Since the transformers were very nearly balanced, wave forms were not recorded upon all of the phases.

Tests with One Transformer

Before investigating the wave forms with the three-phase connections, an oscillogram of exciting current with

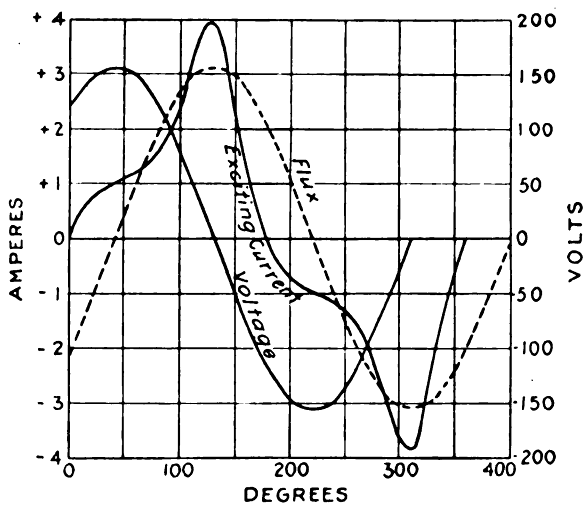


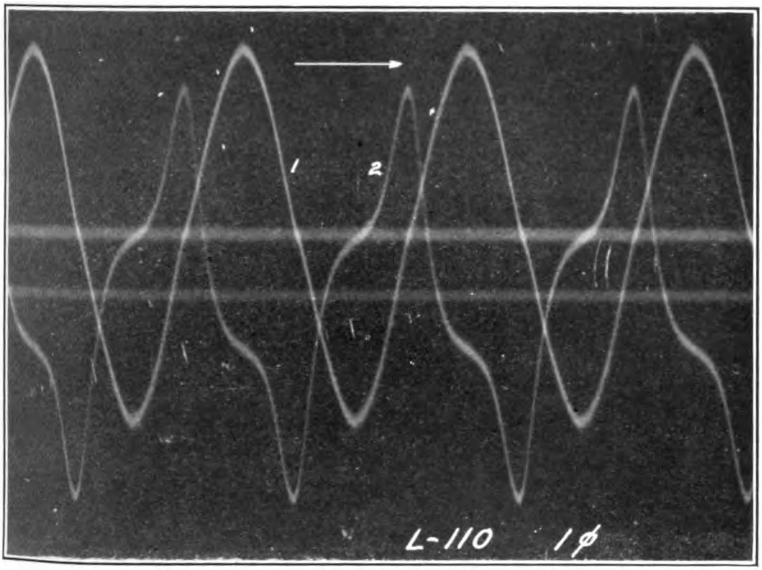
FIG. 2—POTENTIAL, FLUX AND CURRENT WAVES. SINGLE-PHASE CONNECTION

a sine wave of e.m.f. was taken to determine the hysteresis cycle on normal conditions. This is shown in Fig. 1.

Fig. 2 shows the voltage, flux and exciting current, and Fig. 3, the resulting hysteresis cycle scaled from the original oscillogram.

Tests with Star-Connected Generator

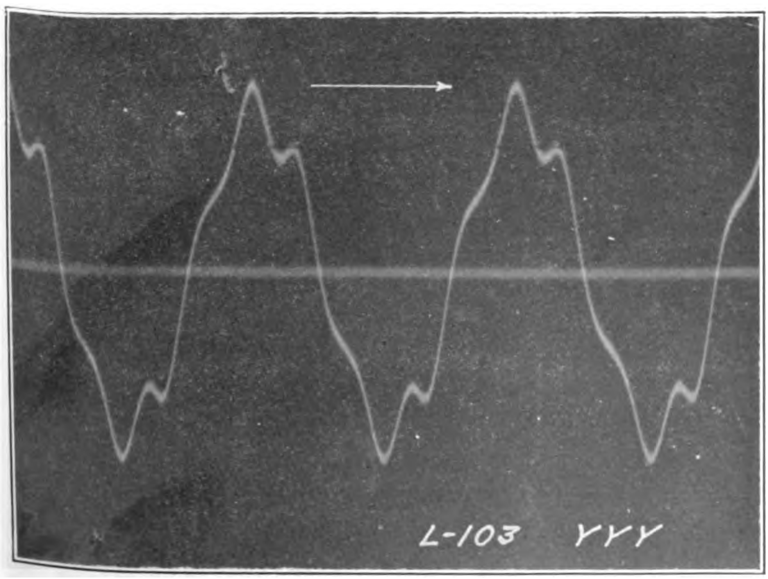
The next set of tests was run with the generator connected in star. This gave practically a sine wave of e.m.f. between lines, except when the reactions in the transformers introduced a fifth harmonic.



[CURTIS]

FIG. 1—EXCITING CURRENT AND POTENTIAL WAVES

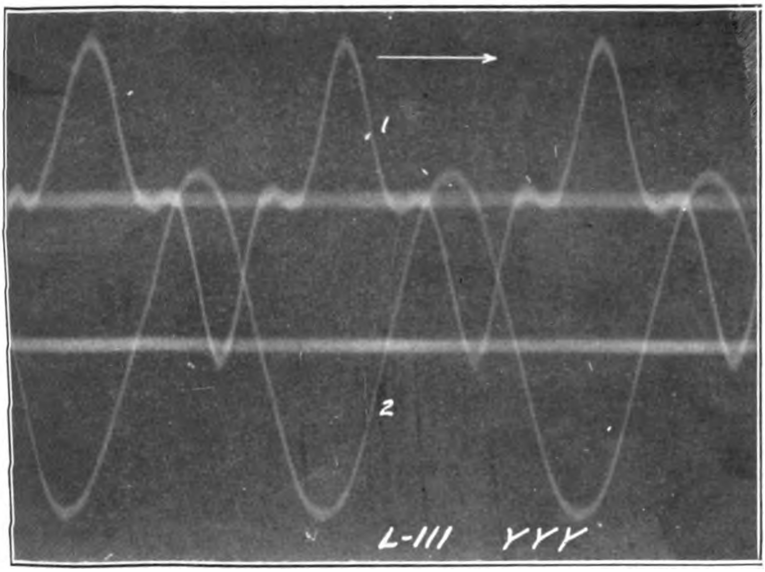
Single-phase connection. Curve 1, voltage across transformer, 110.0 volts. Curve 2, exciting current, 2.00 amperes.



[CURTIS]

FIG. 4—EXCITING CURRENT WAVE

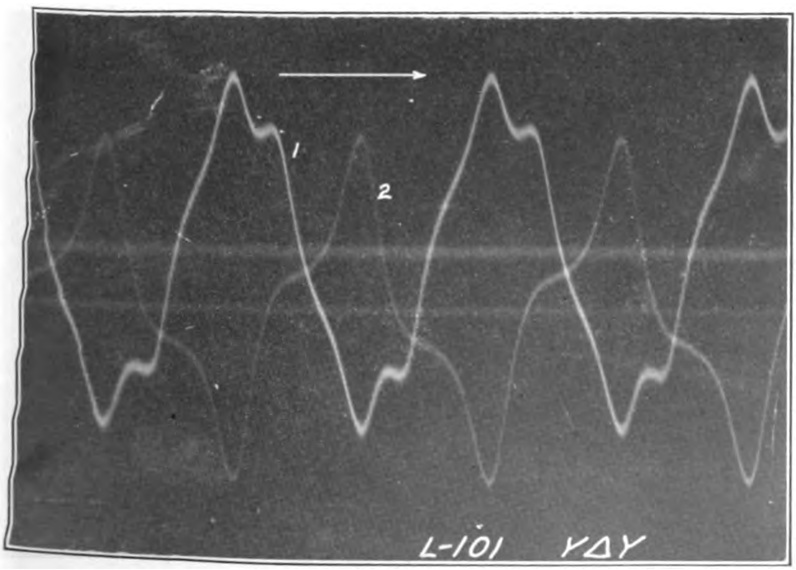
Star-Star-Star Connection.



[CURTIS]

FIG. 5—POTENTIAL WAVES

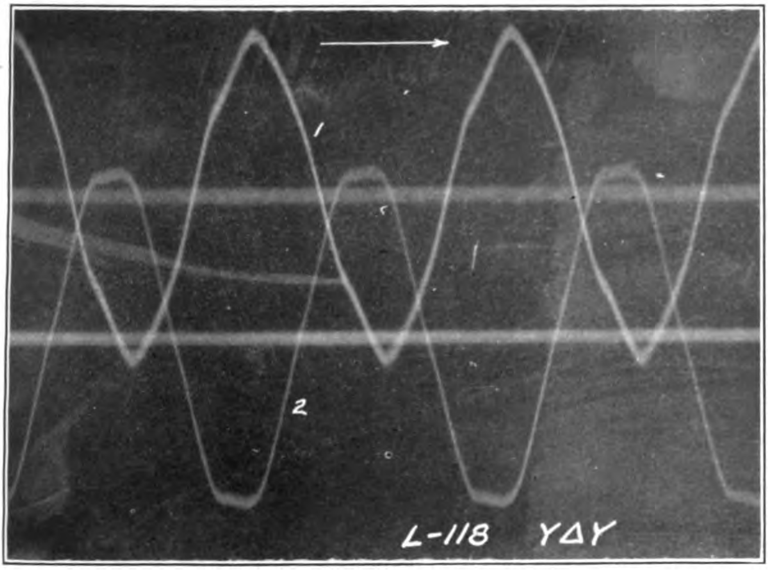
Star-Star-Star Connection. Curve 1, voltage to neutral, 121.0 volts. Curve 2, voltage between lines, 190.3 volts.



[CURTIS]

FIG. 7—EXCITING CURRENT WAVES

Star-delta-star connection. Curve 1, line current, 3.39 amperes. Curve 2, transformer current, 2.11 amperes.



[CURTIS]

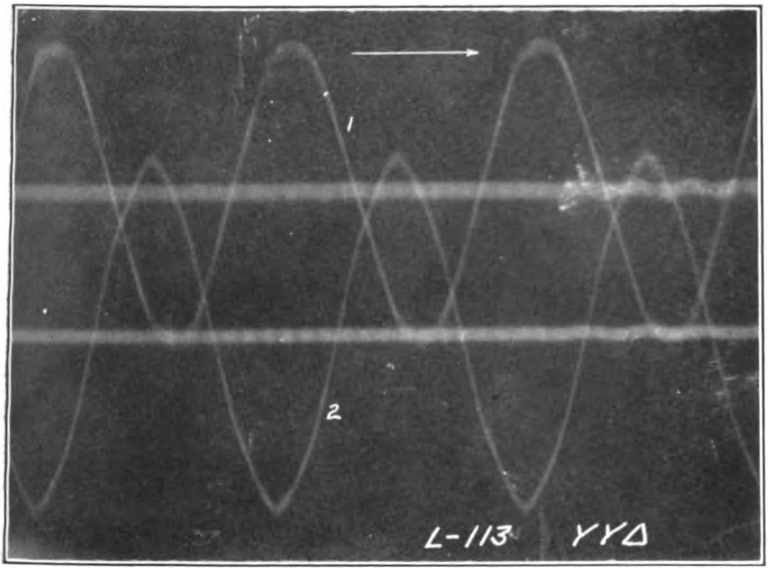
FIG. 8—POTENTIAL WAVES

Star-delta-star connection. Curve 1. line voltage 1924.0 volts. Curve 2. delta voltage 110.0 volts.

[CURTIS]

FIG. 9—EXCITING CURRENT WAVES

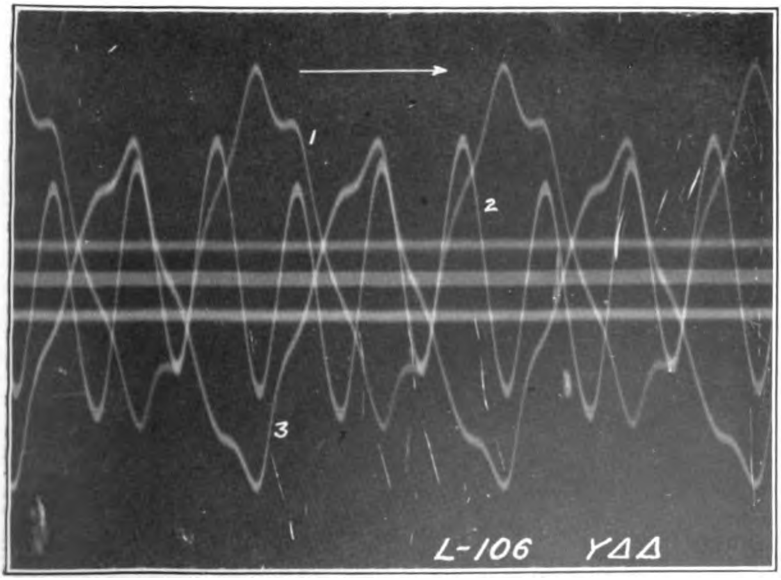
Star-Star-Delta Connection. Curve 1 delta current 0.074 ampere. Curve 2 line current. 1.94 amperes.



[CURTIS]

FIG. 10—POTENTIAL WAVES

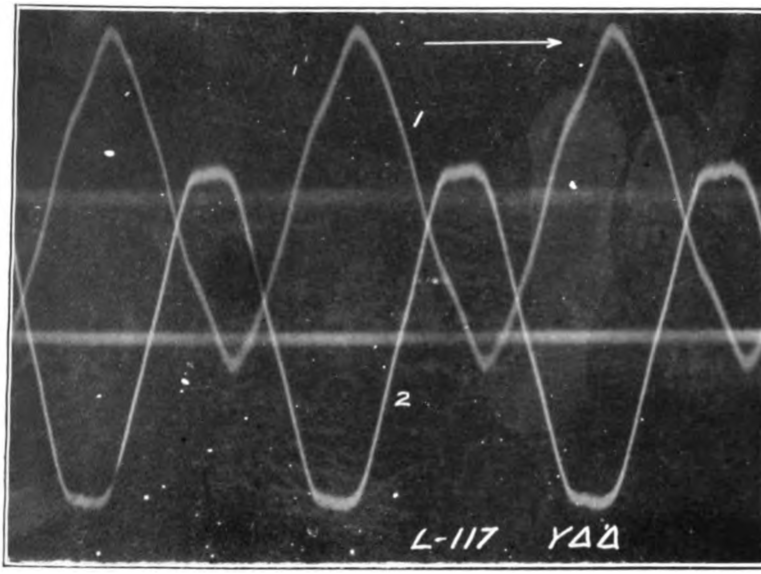
Star-star-delta connection. Curve 1. voltage to neutral, 110.0 volts. Curve 2, line voltage, 190.3 volts.



[CURTIS]

FIG. 11—EXCITING CURRENT WAVES

Star-Delta-Delta Connection. Curve 1, line current, 3.49 amperes. Curve 2, high-tension delta current, 0.068 ampere. Curve 3, low-tension delta current, 2.15 amperes.



[CURTIS]

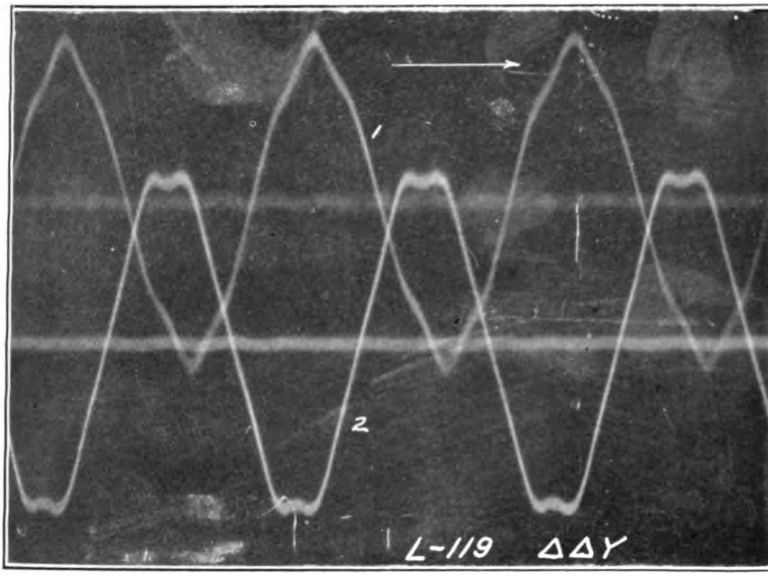
FIG. 12—POTENTIAL WAVES

Star-Delta-Delta Connection. Curve 1, voltage to generator neutral, 63.8 volts. Curve 2, line voltage, 110.0 volts.

[CURTIS]

FIG. 13—POTENTIAL WAVES

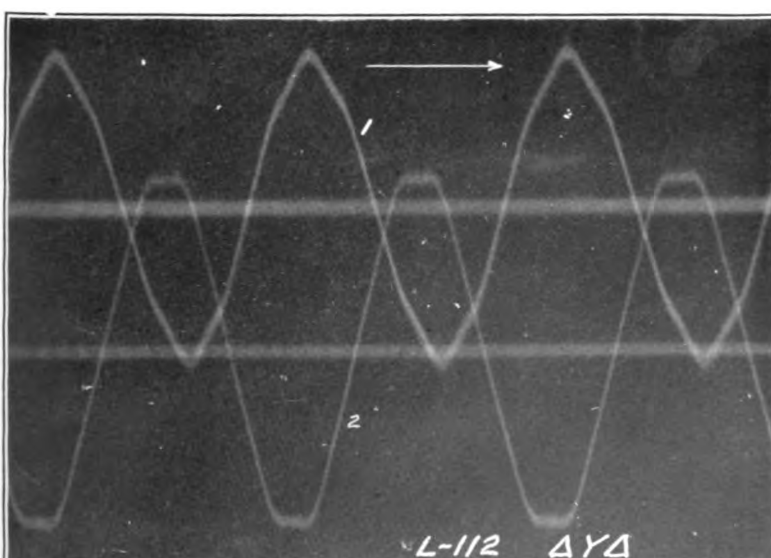
Delta-star-star connection. Curve 1, voltage to neutral, 121.1 volts. Curve 2, line voltage, 190.3 volts.



[CURTIS]

FIG. 14—POTENTIAL WAVES

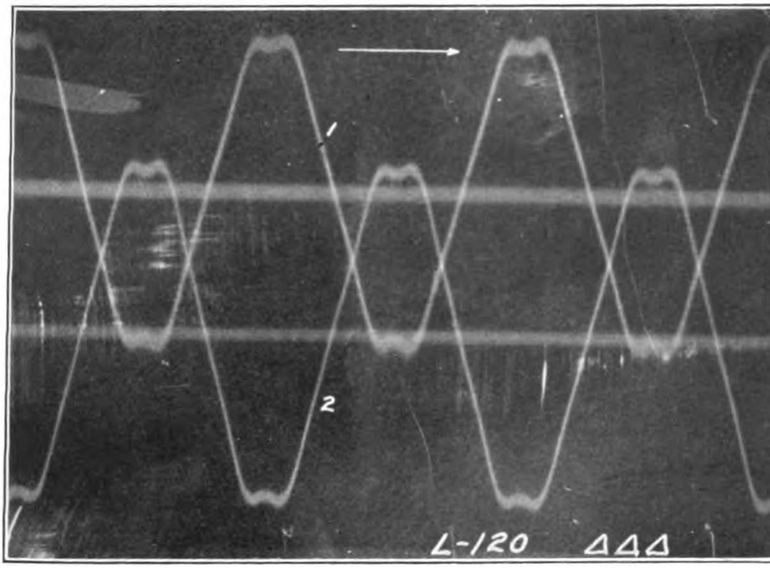
Delta-delta-star connection. Curve 1, line voltage, 1930.0 volts. Curve 2, delta voltage, 110.0 volts.



[CURTIS]

FIG. 15—POTENTIAL WAVES

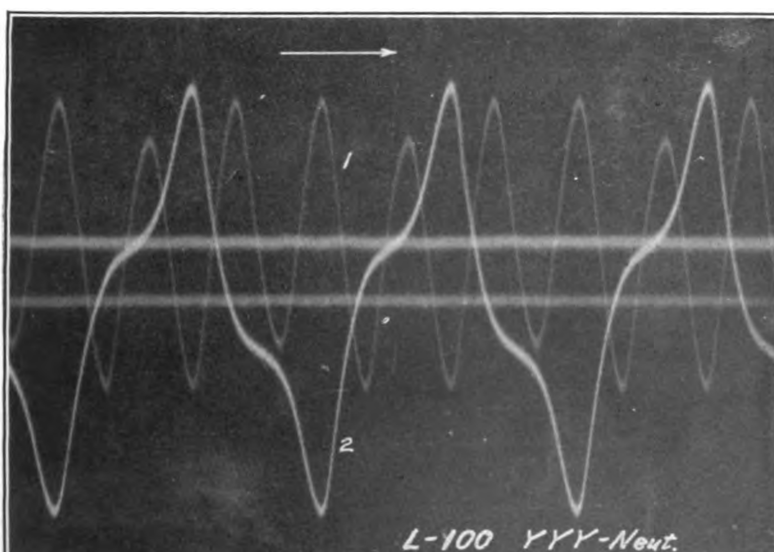
Delta-star-delta connection. Curve 1, voltage to neutral, 110.1 volts. Curve 2, line voltage, 190.3 volts.



CURTIS]

FIG. 16—POTENTIAL WAVES

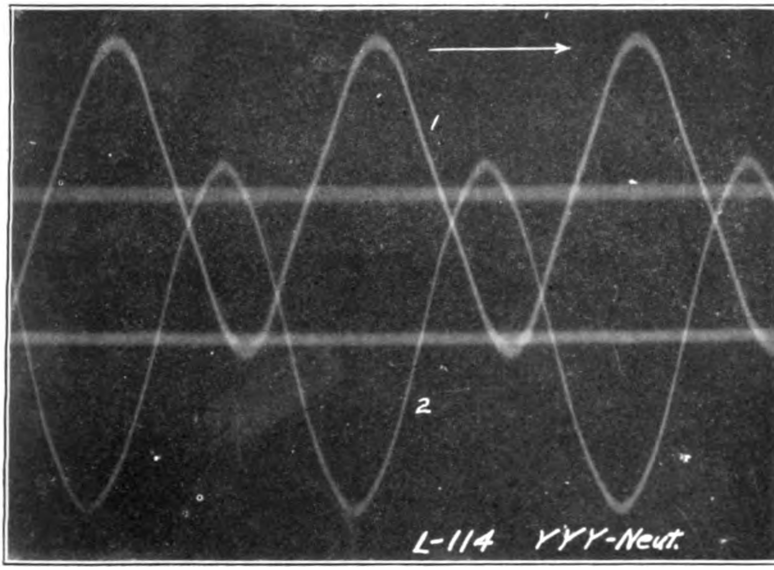
Delta-delta-delta connection. Curve 1, low-tension voltage, 110.0 volts. Curve 2, high-tension voltage, 1110.0 volts.



[CURTIS]

FIG. 17—EXCITING CURRENT WAVES

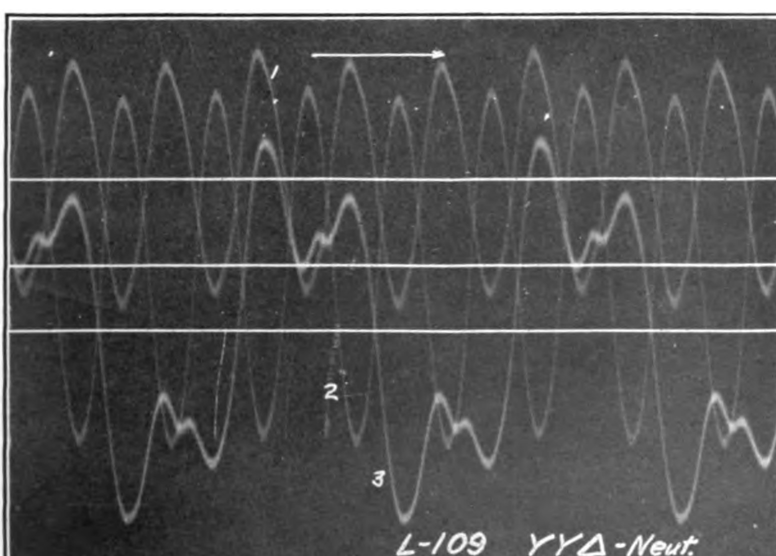
Star-neutral-star-star connection. Curve 1, neutral current, 1.83 amperes. Curve 2, line current, 1.99 amperes.



[CURTIS]

FIG. 18—POTENTIAL WAVES

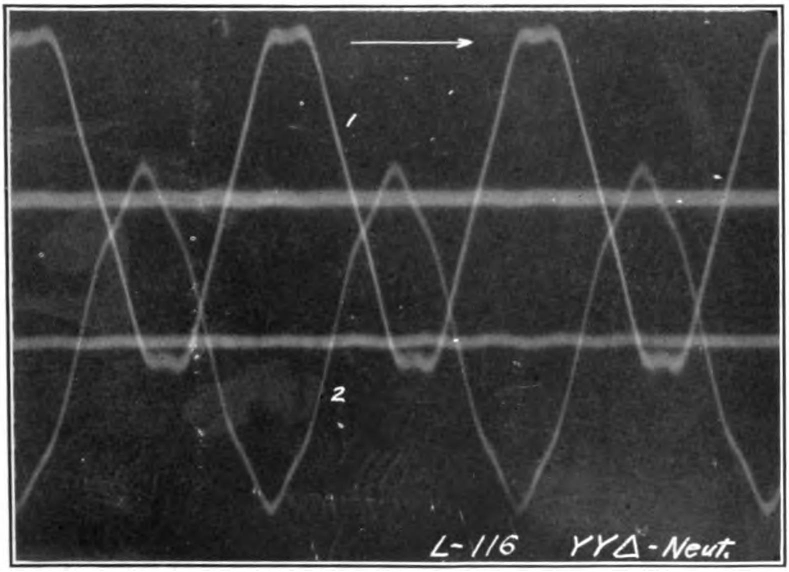
Star-neutral-star-star connection. Curve 1. voltage to neutral, 110.6 volts. Curve 2 line voltage, 190.3 volts.



[CURTIS]

FIG. 19—EXCITING CURRENT WAVES

Star-neutral-star-delta connection. Curve 1, neutral current, 3.55 amperes. Curve 2, delta current, 0.186 ampere. Curve 3, line current, 2.23 amperes.



[CURTIS]

FIG. 20—POTENTIAL WAVES

Star-neutral-star-delta connection. Curve 1, voltage to neutral, 110.2 volts. Curve 2, line voltage, 190.3 volts.

With a star-star connection of transformers, the wave of exciting current is as in Fig. 4. Since no third harmonic can exist in the exciting current, one must appear in the transformer voltage, or the voltage to neutral, even though the line voltage remains a sine wave, because of the definite shape of the hysteresis cycle. This is shown in Fig. 5.

Fig. 6 shows the voltage, flux and exciting-current relations for the above connection. The hysteresis cycle is plotted in Fig. 3, showing the same general shape as for the sine wave of flux, but being smaller in area.

For the above test, normal line voltage (110 $\sqrt{3}$ volts) was

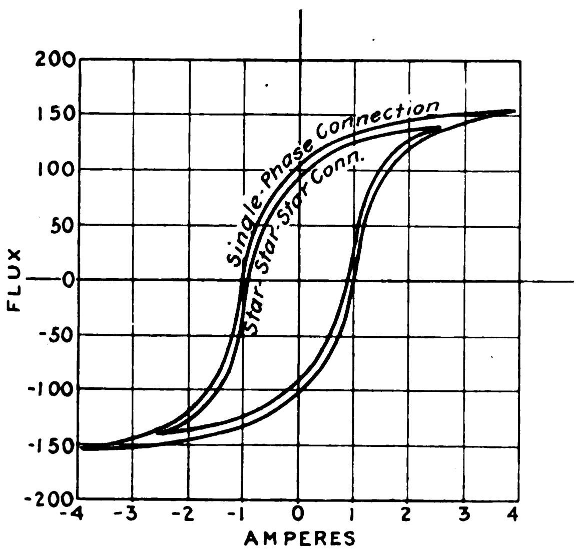


FIG. 3—HYSTERESIS CYCLES

held, but owing to the change in wave shape, the voltage to neutral was 121.0.

With one side of the transformers connected in delta, the third harmonic, which is lacking in the exciting current with the star-star connection, may flow in the closed delta. It appears only in the local transformer circuit. Fig. 7 shows the line current and the transformer current for a delta-star connection of windings. The admittance of the transformers is such that a fifth harmonic in excess of the amount demanded by the hysteresis cycle appears in the line and transformer currents. This causes a fifth harmonic to appear in the e.m.f.

waves, as is shown in Fig. 8. Curve 2 shows the characteristic flat-topped delta voltage, or high-tension voltage to neutral, for this connection. Curve 1 shows the high-tension line voltage, which is peaked because of the vector difference of waves containing the fifth harmonic similar to that shown in Curve 2, 120 deg. apart.

It will be noted that the reaction causing this distortion originates in the transformers, since the wave of exciting current

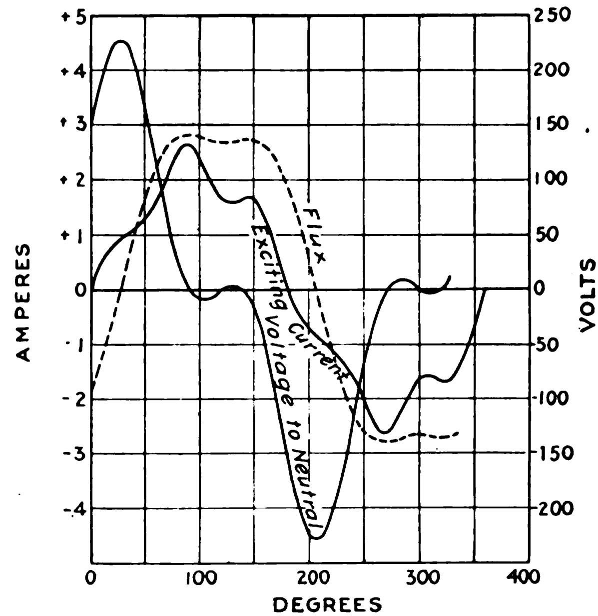


FIG. 6—POTENTIAL, FLUX AND CURRENT WAVES. STAR-STAR-STAR CONNECTION

is not materially different from that of the star-star connection which did not distort the generator voltage.

Fig. 9 shows the exciting currents for a star-delta connection of transformers. The third harmonic of the exciting ampere-turns is now derived from the high-tension delta circuit. The low-tension line current contains an excess of the fifth harmonic as in the previous case, causing the same flat-topped wave of voltage to neutral or delta voltage as before. The transformer and line voltages are given in Fig. 10.

For a delta-delta connection of transformers, the voltage distortions are apt to be increased, due to the troublesome

fifth harmonics in the exciting circuits. The currents and voltages for this connection are shown in Figs. 11 and 12.

Tests with Delta-Connected Generator

With the generator connected in delta, the short-circuit third harmonic current in the armature produces a pulsation at six times the normal frequency in the field flux, which, in turn, introduces a fifth and a seventh harmonic in the armature voltage. Of these, the fifth is the more troublesome, producing the familiar flat-topped wave of delta voltage.

Distortions due to the transformer connections are superimposed upon the generator wave. Figs. 13, 14, 15 and 16 show the voltages of the banks of transformers connected in star-star, delta-star, star-delta and delta-delta respectively, when excited from the delta-connected generator. The original wave form of the generator voltage is shown in Fig. 13, since the star-star connection of transformers does not distort the line voltage.

Tests with Connected Neutral

When the generator and the low-tension side of the transformers are connected in star with connected neutral, the third harmonic components of the exciting current may return to the generator over the neutral, each phase constituting a single-phase circuit.

The waves of exciting current for a star-star bank of transformers with connection to the generator neutral are shown in Fig. 17. The voltages are shown in Fig. 18, being very nearly sine waves.

If the high-tension side is now placed in delta, there exists a short circuit of the unbalanced third harmonics in the three transformers. This causes an excessive third-harmonic current to flow over the neutral which reacts upon the generator flux in the same way as that in a delta-connected generator. This is shown in Fig. 19. A flat-topped wave of voltage to neutral and a peaked line voltage result, as shown in Fig. 20.

Preferable Connections

From the above results it is seen, from the standpoint of wave form, that the banks of transformers connected delta-star, star-delta, or star-star with connected generator neutral give the best results. The latter connection would be ruled out if dissimilar banks were to be operated in parallel.

To be presented at the Pacific Coast Meeting of the American Institute of Electrical Engineers, Spokane, Wash., Sept. 9-11, 1914.

ECONOMY IN THE OPERATION OF 55,000-VOLT INSULATORS

BY M. T. CRAWFORD

ABSTRACT OF PAPER

The author gives a brief outline of the operating experiences on three 55,000-volt lines, two of which have been in service 10 years and one 5 years. The quality of the more modern porcelain insulators is notably superior to those first installed on these lines. A device is described by means of which defective insulators can be readily detected in the very early stages of deterioration, and by periodic use of this device and replacement of insulators, failures in service have been practically eliminated.

THE final measure of success in a transmission system is the cost of securing the desired performance therefrom. The failure of line insulators from breakage or electrical causes is a menace to service performance, and may be the cause of heavy maintenance expense if the failures are frequent and repairs must be made under emergency conditions.

The problem of securing satisfactory and economical operation from lines having gradually weakening insulators, has recently become an important one on some systems.

This paper outlines briefly the operating experience on several of the older lines of the Puget Sound Traction, Light and Power Company system, and describes methods employed to secure satisfactory performance economically.

GENERAL DATA

Nominal voltage, 55,000; non-grounded neutral; 60-cycle, three-phase current. All pin type insulators are of the design shown in Fig. 1.

Line A. In service 10 years, from Electron generating station to Tacoma. Length, 31 miles (49.8 km.). Number of insulators, 4450. Poles, 40-ft. (12-m.), set on average spans of 125 ft. (38 m.). Wires spaced six ft. (1.8 m.). No. 4/0 B. & S. copper 21 miles (33.7 km.); No. 0 B. & S. copper 10 miles (16 km.). Insulators comented on iron pins. Wooden pins screwed in insulators were used on a portion of this line when

first installed, but have nearly all been replaced at this date with iron pins.

Line B. In service 10 years; from Electron generating station to Seattle. Length 47 miles (75.6 km.). Number of insulators 6850. Poles 40 ft. (12-m.), set on average spans of 125 ft. (38 m.). Wires spaced six ft. (1.8 m.). No. 4/0 B. & S. copper. Insulators cemented on iron pins.

Line C. In service five years at 55,000 volts; from Snoqualmie generating stations to Everett, Seattle and Tacoma. Length 160 miles (257.4 km.). Number of insulators 17,350, 4550 of which were in service at 30,000 volts for two years previous

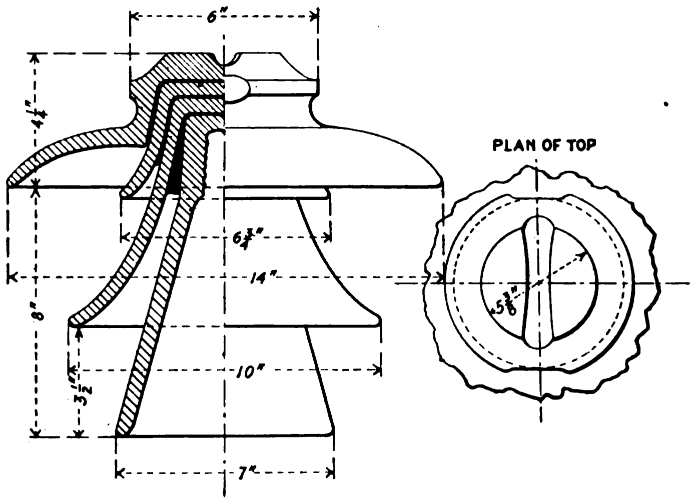


FIG. 1—INSULATOR FOR 60,000-VOLT CONSTRUCTION.

to the 55,000-volt service. Poles 35- to 55-ft. (10.6- to 16.7-m.), set on spans from 130 to 300 ft. (39.6 to 91.4 m.). Wires spaced seven and nine ft. (2.1 and 2.7 m.), and vary in size from No. 4 B. & S. copper to No. 4/0 B. & S. aluminum. Insulators screwed on iron pins.

OPERATING HISTORY

Line A. The insulators originally installed on Line A were among the first of their kind and voltage to be made, and the art of high-voltage porcelain manufacture was not well understood at that date. Their appearance indicates that the clay was worked quite dry and that probably the mixture contained

a much lower percentage of china clay than is now used. Many samples show a lack of homogeneity in the ware and irregularities of surface, and firing cracks are visible under the glaze. The shells were given a moderate test at the factory and shipped to Tacoma, where they were cemented together and the assembled insulators subjected to a dry test of 120,000 volts. Difficulties with the testing equipment made it necessary to put a portion of the insulators on the line without test. There were failures from time to time during the test, but as it was considered unusually severe, trouble was not anticipated.

Electrical failures began to occur within a short time after installation, especially during line surges and in wet weather, and have continued from time to time to date. The larger shells crack radially and leakage over the smaller shells burns off crossarms. These cracks stand open perceptibly, indicating that there were shrinkage strains in the ware.

It has been necessary gradually to replace these insulators, until at this date 83 per cent of the original installation has been replaced.

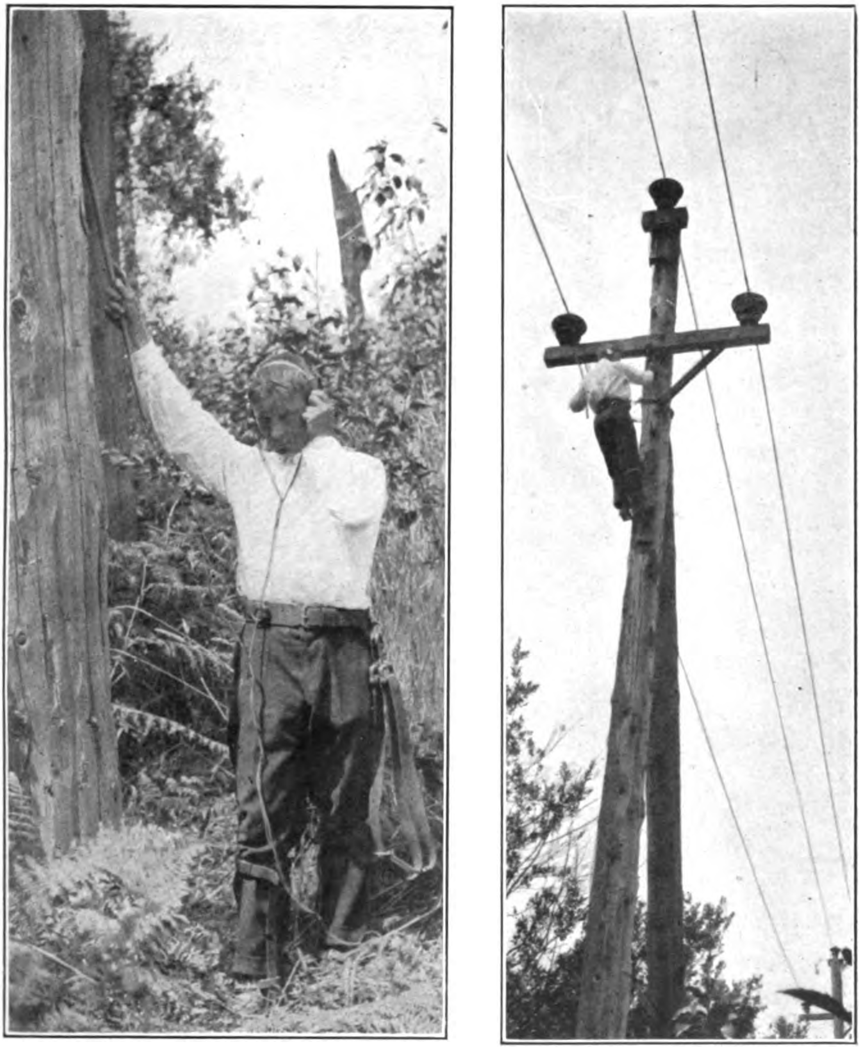
Line B. The insulators on this line were purchased and installed under the same conditions as Line A, but were made at a different factory. The appearance of these insulators indicates a much better grade of porcelain with a smoother surface, but some samples of them do not compare with the ware turned out of the factories today. Such of them as were tested showed a very small percentage of failures. For the first five years of operation, very little trouble was experienced with these insulators, but later on they began breaking down occasionally and recently they have given a good deal of trouble, failing several at a time during an arcing ground at another point on the system. A large number of these insulators were put on Line A to replace failures of the original insulators thereon, so that the total installation of the ware purchased for Line B is about 8200 insulators. Of these, the failures to date have totaled about 4 per cent, nearly half of which have been in the last year. These insulators do not usually have a large radial crack, but a small crack starts on the head or in the side groove and runs around on the top of the insulator. It seems that these cracks enlarge until a leakage current starts through the top two or three shells and discharges over the surface of the lower shell. The tendency of a brush discharge to pass in the positive direction more than the negative, has

a rectifying effect on the leakage current. This results in a partly unidirectional current from the bottom shell to the pin, and signs of electrolytic corrosion of the pin head in the cement have frequently been found. Once started, this will soon crack the entire insulator, as the high tensile stress put on the porcelain by this internal expansion will lower its dielectric strength. In many cases insulators have been found which were leaking noisily, and when the line was killed and an examination made, the insulator was found intact, although a number of cracks were visible. As soon as the tie wire was removed, however, the entire insulator fell apart.

Line C. The insulators on this line were made at several different factories and are of as fine a grade of porcelain as can be obtained today. A representative of the company at the factory tested each shell separately, and the assembled insulator, to 120,000 volts for five minutes. Every insulator was given this test and examined for physical defects, and stamped by the inspector if accepted. To date there have been only three failures, and it is possible that these were partially broken in some other way before failure.

A large number of insulators have been installed on pole lines and steel tower lines built within the last few years on this system, which were tested as in Line C and screwed on iron pins, and there have been no failures. About 120 strain insulators, each consisting of three 10-in. (25.4-cm.) diameter link type disks with no cemented parts, have been in service at strain points for three years without trouble.

The expense of replacing outright all the Line B insulators was prohibitive, and they formerly were replaced one by one when they got to the point where the leakage currents could be heard from the ground. This was not entirely satisfactory, however, as they were at an advanced stage of the deterioration before this condition was reached, and frequently failed, causing an arcing ground that punctured other insulators, and a heavy charge against maintenance resulted on account of the emergency nature of the repair work. The first method tried was by using a megger, but no satisfactory results could be obtained unless the testing wire was over the leaking crack and this crack extended clear through to the pin. Each insulator had to be untied and the testing work was very expensive and laborious. After considerable experimenting a device was perfected to locate these insulators at an early stage of the



[CRAWFORD]

FIG. 2—SHOWING METHOD OF USING DEFECTIVE-INSULATOR DETECTING SET

Hand pick consists of insulated tube with sharp pointed steel terminal on one end which is thrust into the pole or crossarm. A sharp steel pin forms the other terminal, which is driven into the ground or pole under the cross arm. A fuse and short-circuiting jack with plug on the receiver set may be inserted in the circuit if there is any probability of a considerable voltage to ground.

depreciating process, so that the work of replacing them could be done economically and before they broke down and damaged other insulators and interrupted service. This device is shown in Fig. (2) and consists of a pair of 2000-ohm wireless telegraph receivers, fitted up for the convenience and safety of the inspector in testing. The hand pick is driven into the pole about seven feet from the ground, and the sharpened pin driven into the ground several feet away. The receiver set is connected between these two, and if all insulators are sound there is a clear audible hum of the same tone as the telephone line, due to the shunting of a part of the capacity current of the insulators on the pole top. If, however, one of them is leaking, a scratching noise is superimposed on the hum, which comes and goes as the neutral shifts to and from the wire on the defective insulator. The inspector then proceeds up the pole and tests between each insulator pin and the center of the crossarm, and thus locates the defective one. This device can be used in a similar manner on steel tower lines. Insulators can be found in this way which have only a very small crack started and which will not puncture on the test below 100,000 volts. Insulators with a crack clear around the head were taken off and tested, puncturing at from 60,000 to 65,000 volts, but no sound was audible from them while on the line without the use of the detecting set. One or two lower petticoats were usually found intact, the leakage current passing over their surface during the test until the puncture point was reached.

Field books are kept with the record of the last test, and data on each insulator on every pole in Lines A and B. With practise the inspector can single out defective insulators which are at an early stage of the depreciating process. These tests can be made while the lines are in service, at very slight additional cost to the routine patrolling. Several hundred insulators can then be replaced at a convenient time and the work organized so as to be done economically. By keeping at this work at regular intervals, failures in service can be practically eliminated.

It seems probable from the history of operation that the porcelain on Lines A and B was of lower dielectric strength originally than that on Line C, and that many of these insulators were therefore under an electric stress, which was a large percentage of their ultimate strength. Under these conditions

the poorer insulators soon failed, and the better ones gradually weakened, to fail later. The best insulators however, as on Line C, are being operated at a potential which is a small percentage of their ultimate strength and are showing no signs whatever of weakening or fatigue, although they have only been in service five years. The Line A and Line B insulators began to weaken in less time than this, and it seems that if any process of fatigue were under way, some signs of it would surely be in evidence among 17,350 insulators after five years' service. Although the evidence is not conclusive, it seems probable to the writer that electrical fatigue of porcelain only occurs where the ware is operated under electrical or mechanical or combined stresses which are too close to its ultimate strength. Insulators should be designed and individually tested to withstand at least $2\frac{1}{4}$ times line voltage; and care should be taken that at high potentials, where unit insulators are in series, line voltage is taken as the actual portion of the total voltage which comes on each particular insulator in the string. Where the gradient is not uniform and potential is concentrated more on some units than on others, these units should be designed accordingly and tested as above.

The use of cemented-in metal parts should be avoided in connection with porcelain insulators, thus eliminating any possible trouble due to electrolytic corrosion if leakage currents occur, or due to expansion and contraction strains of the different substances. The use of screwed-on pin-type insulators decreases the cost of replacing, and while not quite as suitable for heavy side strains, the use of strain insulators is better practise for such points.

To be presented at the Pacific Coast Meeting of the American Institute of Electrical Engineers, Spokane, Wash., Sept. 9-11, 1914.

APPLICATION OF ELECTRIC MOTORS TO GOLD DREDGES

BY GIRARD B. ROSENBLATT

ABSTRACT OF PAPER

Electric power has been applied almost universally to the operation of gold dredges of late, owing to its convenience and to the fact that hydroelectric power is available at very reasonable rates throughout the western states where gold dredging is carried on. There are a number of different motor applications on the elevator type of gold dredge, which is the type most generally used, and the author considers very fully the requirements of the various drives and the characteristics of the motors suited to the various operations of these dredges. Alternating-current motors are generally used for these purposes and the type of control, which is of special importance, is considered. The paper also gives some figures on the cost of operation of dredges of different capacities.

A GOLD dredge is a piece of machinery designed to dig gold-bearing gravel, sand, or clay, and to treat the material so dug in such a way as to recover the gold contents. It, accordingly, consists essentially of two parts; one the digging part and the other the gold saving part.

From the point of view of the application of electric power the digging end is of particular interest as the mechanical requirements are severe and the speed control must be exceptionally good. The gold saving end does not differ very materially as to motor applications from those of the usual metal mining mills, except possibly that the equipment is exposed to a little more abuse and that compact methods of drive are necessitated.

Electric power has been applied quite universally of late to the driving of gold dredges owing to its convenience and economy. Of the $88,400,000.00 worth of gold produced last year in the United States, nearly a fifth came from gold dredges, and in view of the fact that gold is being mined by means of dredges in practically all of the Western States, in most of which localities hydroelectric central station power is available, a few remarks regarding the essential characteristics of successful motor drive may be of interest.

In designing electrical apparatus and applying it to gold dredging, the electrical engineer is often too prone to approach the problem from the point of view that the dredge should be designed particularly to permit of the most favorable application of electrical apparatus. A successful gold dredge is primarily designed to make money. Electric drive is merely an incident in the process, so that, while it is unquestionably often advantageous to modify the ordinary dredge design so as to better accommodate it to the characteristics of the electric drive, nevertheless the fact should not be lost sight of that the electric drive is simply an incident to effect economy and that other considerations are often of greater importance than the most advantageous installation of a particular type of motor in a particular manner.

In considering how electric drive can help the dredge make money, the following factors enter into the total charge against the electric plant:

1. Interest on investment; which is affected by the first cost of any particular arrangement.

2. Power charges; which are affected by the efficiency of the motors and the system of control.

3. Maintenance charges; which are affected by the type of apparatus chosen.

4. Delay charges; which may be very seriously affected by proper or improper application.

As stated above, the gold saving end of a dredge does not offer any particularly great problems in the application of electric drive. A motor is required to drive either a shaking or revolving screen which removes the coarse rock from the finer gold-bearing sands and gravel. This motor may be either geared or belted to the screen. Gearing is preferable on account of its saving in space, but belt drive is preferable as far as the motor is concerned on account of the damping effect upon the vibration incident to the screening operations. Squirrel-cage motors are generally used for this purpose and are entirely successful, but some designers advocate motors with phase-wound secondaries in order to reduce the strain at starting. The writer is inclined to favor the squirrel cage motor on account of its freedom from details which may increase the maintenance charge.

All of the gravel and sand which passes through the screen must be washed in order to obtain the gold out of it, and for this purpose a very considerable volume of water must be pumped

on the bridge. Centrifugal pumps are usually used on account of the low head and large volume to be handled, and these are best driven by direct-connected squirrel cage motors. Apart from those features which tend to reduce the maintenance charge, such as adequate insulation, adequate air gap, and adequate bearings, the efficiency of these pump motors deserves consideration as the amount of the total power used by the dredge used for pumping is very considerable, usually as high as 40 per cent, and sometimes higher.

The tailings, or refuse matter that is sorted out by the screen, must be removed to some distance from the hull of the dredge so that it will not pile up under the hull and strand the dredge. Two methods of taking care of this matter are in use. One, the less common, is to pass the waste down a chute, helping its progress with a stream of water. The other, and by far the more common method is to employ a belt conveyer running out of the back end of the dredge for a distance of 90 ft. (27.4 m.) or more, which conveyer is commonly referred to in dredge practise as a "stacker". This stacker is motor-driven. The application is reasonably severe owing to the fact that the motor is usually at the far end of the stacker and, therefore, often exposed to the weather, and also due to the fact that when the stacker has been at rest, considerable torque is required to start it loaded. In cold climates, a stacker when at rest is often apt to freeze, due to the moisture contained in the waste being carried by it. Starting under these conditions is particularly arduous and in some places this trouble is overcome by putting the stacker in a continuous canvas tent like a tunnel and passing steam pipes from a little low pressure heating boiler up inside this tent. This again makes life hard for the motor because moisture vaporized by the heat of the steam pipes rises to the far end of the stacker where the motor is located, and there often condenses on the motor whenever that machine is shut down and allowed to cool. Accordingly, a motor for stacker service should primarily be designed with adequate insulation to resist continued moisture, and in some cases drip guards have advantageously been placed over the ventilating openings in the motor. Squirrel cage motors with heavy torque characteristics have been used successfully for stacker drive, but the general tendency is to use motors with phase-wound rotors in order to obtain a good starting torque. Here again is the question whether complications of a phase-wound motor are justifiable, and in the writer's opinion it is

probably preferable to use a squirrel cage motor designed for good torque characteristics, with possibly a trifle more resistance in the secondary circuit than is found in standard squirrel cage induction motors. A stacker motor is comparatively small as compared with the total motor installation on the dredge, and a slight loss in efficiency on such a small unit is more than offset by a saving in maintenance.

The application of electric power to that portion of the mechanism used for digging is a much greater problem than anything met with in connection with the other applications on the dredge.

There are three distinct types of gold dredges using entirely different digging mechanisms: (a) dipper dredges, (b) suction dredges, and (c) elevator dredges.

(a) The dipper dredge uses a boom and scoop almost exactly like a steam shovel. It is now practically obsolete in the gold dredging industry because of its poor power economy and because the dipper is actually digging dirt during a very small portion of the time that it is in operation. In other words too much time is lost in lifting the loaded dipper, dumping it, and returning it to the digging position.

(b) The suction dredge is very similar to the ordinary dredges used in harbor and waterways excavations. Its digging end consists essentially of a large centrifugal pump suitable for handling semi-solid material, and is driven by a direct-connected varying-speed induction motor. The suction dredge is applicable for gold mining only in those few localities where water is very abundant and where the gold is found in loose sand. Its application to the gold mining industry is so limited that its details will not be discussed in this paper. It has the particular advantage, however, that its operation is continuous.

(c) The elevator dredge is the most commonly used for gold mining. It is essentially a continuously operating dipper dredge, combining all of the advantages of the steam shovel with the continuity of the suction dredge. A chain of scoops, or " buckets " as they are called, runs over a boom or "ladder," as it is commonly termed. This boom or ladder is swung from a gallows frame or derrick, and by properly manipulating the cables that control it, the boom is held up against the bank to be dug, and the bucket chain driven by a motor, so that each bucket scoops up its fill of earth as it comes round the end of the boom and carries its load without interruption to the mouth of the screen described

above Fig. 1 shows the essential parts of an elevator gold dredge as described above. The illustrations on Plate LXXVII show some typical elevator dredges and show very clearly the boom, the bucket chain, and the gallows frame from which it is suspended.

Power is required at the digging end primarily for driving the bucket chain, but some power is also required for lifting and lowering the ladder and for operating the devices that pull or hold the dredge up against the bank so that the buckets will bite into their work. Ordinary winches similar to those often used on sea-going vessels are used for these purposes. The duty of the motors is entirely akin to ordinary hoisting service and of very intermittent nature. An intermittent rated wound-rotor motor with high torque characteristics is successfully used.

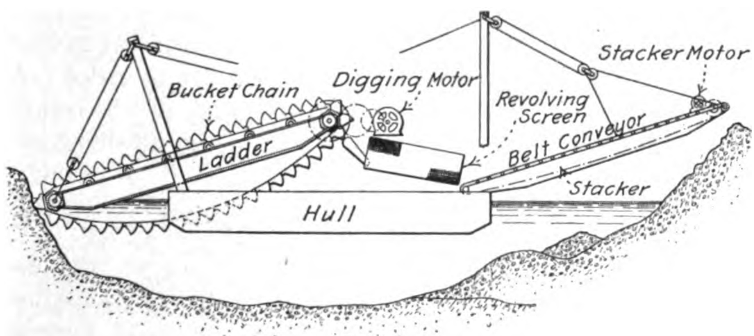


FIG. 1—ESSENTIAL MECHANISM OF AN ELEVATOR-TYPE GOLD DREDGE

The drive of the bucket chain is the real problem on the dredge and no system that has ever as yet been devised has proven itself entirely free from all objections. For one thing, power requirements are at times very excessive and vary through a wide range. Accurate speed control is also essential. Good economy is of importance on account of the comparative size of the digging motor compared with the rest of the installation (in this connection it might be stated that the digging notor is usually from 35 per cent to 45 per cent of the total motor capacity on the dredge). Greatest of all is the problem of adequate and successful mechanical connection between the motor itself and the bucket chain.

The power requirements for driving the bucket chain under ordinary conditions may be calculated reasonably closely when the size of buckets, the number of buckets handled per minute

and the type of ground to be dug is taken into consideration. The following table gives some fairly typical test results:

Place	Size of buckets cu. ft.	Buckets per minute.	Motor rating h. p.	Average h.p. input.
Oroville	5	18	75	65
Marysville	7	20	150	140
Marysville	7½	19	200	155
Conrey	9	18	150	185
Natoma	14	21	400	285
Folsom	13½	20	300	202
Boston & Idaho	15	..	300	285 (?)
Conrey	17	22½	550	460

N. B. All close-connected chains,—ordinary digging.

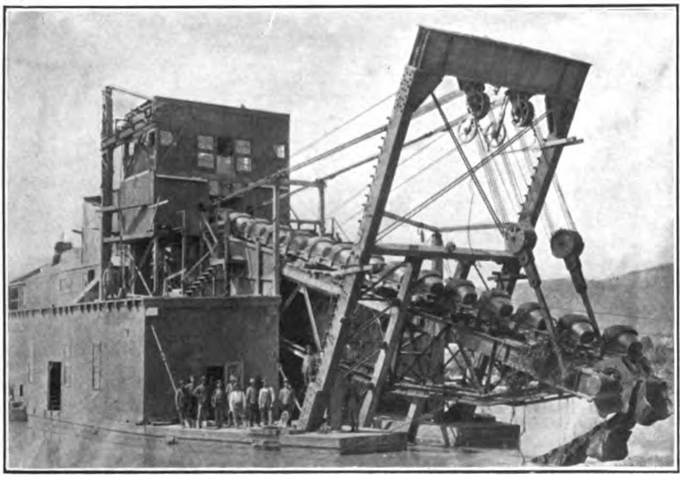
However, should one of the buckets in a bucket chain encounter a boulder of larger size than it can handle, the demand on the motor is immediately increased and may even cause the motor to pull out if no protective devices are provided. Also if the buckets run into particularly sticky clay in the course of their digging, the load on the motor may be very much increased, and as such a condition is seldom momentary, the continuity of the overload may burn out the motor unless the speed of digging is reduced.

In addition to these requirements, during digging the motor drive must also be capable of revolving the bucket chain slowly at no load for the purpose of repairing the buckets, inspecting the chain, and similar work required for the purpose of mechanical maintenance.

The bucket chain is driven through a hexagonal spindle at the top of the ladder over which spindle the buckets pass. Each one of the flat sides of this spindle or "tumbler" as it is termed, engages with a corresponding flat side on the under side of the bucket, and the drive is accordingly a positive drive just like any chain drive would be. If the tumbler turns, the bucket chain has got to move or break. It cannot slip. An adequate and successful method of transmitting power from the driving motor to the tumbler has been the source of considerable study by dredge designers the world over. The tumbler shaft usually carries two pinions, one on each side, which engage with two gear wheels carried on a common shaft. This shaft is connected through an adjustable slipping friction to another drive shaft by means of gearing, and the motor drives the last named shaft. It may be either belted or geared to this shaft. Belting the

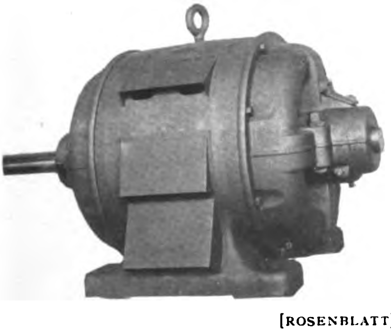
DREDGE WITH 17-CU. FT. BUCKETS. [ROSENBLATT]

Chain is "close-connected", *i.e.* each link of the chain is a bucket. 500-h.p. digging motor and liquid rheostat control; cooling system for electrolyte is visible, dipping into pond at side of dredge.



DREDGE WITH 12-CU. FT. BUCKETS. [ROSENBLATT]

This shows clearly the ladder and the bucket chain. The chain is of the type known as "open-connected", in that there is a link without a bucket between each two buckets.



[ROSENBLATT]

TYPICAL SQUIRREL-CAGE MOTOR, WITH SPLASH-PROOF COVERS, FOR STACKER DRIVE.

motor is of course the easier on the electrical apparatus, but on the other hand has certain disadvantages. A very large and expensive belt is required on account of the tremendous torques involved. There are sometimes difficulties due to maintenance, because of the moisture that is often present on board a dredge. The belt sometimes slips just when maximum torque is wanted. Occasionally, under the heavy stress due to the slipping friction having rusted, a belt will break. Also a belt transmission for the transmission of the torques involved takes up considerable space, and space on a dredge is valuable.

On the other hand, gearing while economical in space and entirely positive in action, has the disadvantage that it imposes very severe service on the electrical equipment, in that every strain and every vibration from the bucket chain finds its way back to the revolving part of the motor. Flexible couplings have been tried between the motor and the driving gear but without success. The large variations in torque met with, sooner or later ruin any type of flexible coupling that has as yet been tried. The gear drive has, however, proven entirely successful where a motor has been secured that will adequately withstand the stresses. Of the two methods, belt vs. gear drive, each has its ardent devotees.

From a consideration of the above, it will be seen that the motor required for digging service on an elevator dredge must have the following characteristics:

(a) It must be varying-speed machine; and if in addition it can be made an adjustable-speed machine this would be a considerable advantage.

(b) It must be capable of being revolved at light loads and very low speeds.

(c) It must be capable of developing a maximum torque at any speed from zero to approximately full load speed of several times its normal rated torque.

(d) It must be capable of carrying for prolonged periods of hard digging a torque overload of approximately 25 per cent at a speed reduction of probably 25 per cent.

(e) It must be of substantial mechanical construction, particularly as to shaft and bearings, in order to resist a very heavy belt pull when belt drive is used, or repeated shocks of severe gear thrusts when gear drive is used.

(f) It must be reasonably efficient.

In order to obtain all of the above characteristics, it has often been suggested that a direct-current motor of the type used in

steel mills, with possibly variable-voltage speed control, might prove advantageous for digging service on big gold dredges. However, every investigation that has been made (to the writer's knowledge) of this matter has developed the fact that the losses in efficiency due to the conversion from alternating current to direct current practically offsets the advantages gained by more flexible control under the ordinary cycle of operation, and further, the first cost of such an installation is prohibitive considering the ordinary life of a dredging venture. In this connection it might be stated that while there are exceptions, the average dredge is about worn out at the end of ten years, and will then require either complete rebuilding and remodeling or will operate with so many shut-downs due to breakages and the like that rebuilding or scrapping will prove most economical. Accordingly any installation more expensive than ordinary must show a saving that will repay the extraordinary expense in 10 years. and this no combination of direct-current equipment has as yet been able to show.

Accordingly the only type of motor left available is the moderate speed wound-rotor induction type, and for the most successful application the motor should be designed with special reference to the work it has to do.

From experience with the troubles of a dozen dredges, large and small, the writer would recommend specifications embodying the following:

(1) The motor should be capable of carrying its rated load continuously with a rise not to exceed 40 deg. in any part.

(2) The motor should be capable of developing a torque 25 per cent in excess of its rated full load torque at a speed of 75 per cent of its synchronous speed for a period of two hours with a rise not to exceed 55 deg.

(3) The motor should have a maximum torque and a starting torque of not less than 2 1/2 times its full-load torque.

(4) The shaft shall be of such material and dimensions that strains due to the developing of maximum torque shall not appreciably affect the dimensions of the air gap on any side of the motor.

(5) The bearings shall be designed to resist an upward thrust, and shall preferably be of the design known as rolling-mill bearings furnished with stud bolts and lock nuts instead of the usual design employing cap screws.

(6) The lubrication of the bearings shall be adequate. On motors of 200 h.p. and over, at least two oil rings per motor are

recommended. On motors of 500 h.p. and over, the use of gravity feed lubrication should be considered.

The problem of control of large motors used for digging service on gold dredges would be more simple if direct-current motors could economically be used. As, however, their use is impractical, the control for a-c. motors that most nearly approaches direct-current control is desirable. The control must permit reversing the direction of the motor, principally to permit the bucket line being backed away from obstructions. For service during the repair of the bucket line, small variations in speed should be obtainable, particularly at partial loads. A control permitting continued running at low-speed points is particularly necessary.

For small motors on little dredges, say employing a digging motor of 100 h.p. or less, the ordinary drum-type controller proves adequate. For larger installations a combination of magnet switches controlled by a master controller has been used in a large number of installations, but for the larger motors the ideal control seems to be the liquid rheostat.

Magnet-switch control has been used satisfactorily on a considerable number of dredges employing digging motors as large as 400 h.p. The very large fleet of large dredges operated in California by the Natomas Consolidated mostly employ magnet-switch control on dredges having digging motors of 300 h.p. and larger. It has, however, several distinct disadvantages for dredge service. The principal disadvantage is that a limited number of definite points only are available with this type of control unless the number of magnet switches in the secondary circuit is made very large, which in turn makes the controller inordinately expensive. Therefore, small variation in speed, particularly at light loads are not available with this type of control, and in order to obtain slow movement to the bucket chain, it is customary to start the motor up and then plug it, with consequent strain on all mechanical parts, as well as wear on the control contacts. Further, this type of control does not allow the dredge operator to pick out any particular speed at which he desires to run. He can only pick a particular point on the controller and the corresponding motor speed will depend on the torque being exerted by the motor.

Another disadvantage of this type of control is the tremendous amount of resistance required for a large motor, as the resistance must be sufficient in amount to permit very low motor speeds at light loads, and large enough in capacity to permit continuous

operation at reduced speeds with heavy torques. This makes a very bulky resistance and unless the resistance is large enough there is considerable danger from overheating of the grids starting a conflagration.

The liquid rheostat for digging motor control has on the other hand none of the disadvantages of the magnetic switch control. There are no definite steps, and the speed of the motor may be varied by infinite gradations. The operator simply moves the rheostat handle until he obtains the speed he desires. In other words, he does not work for any particular point on the rheostat, but works simply with the idea of getting the speed he wants. For large motors, the liquid rheostat and its accessories take up much less room than would a corresponding magnetic switch control and its attendent resistance, and there is never any danger of the electrolyte used (water and common washing soda) causing a conflagration.

However, the liquid rheostat for use on dredges must be modified from the forms commonly used for hoist service and the like on land. The first liquid rheostat installed on dredge service was on one of the Natomas dredges with a 400-h.p. motor, and while it was operative it was not entirely satisfactory because certain essential details of design and application were overlooked. A very similar liquid rheostat on which these details have been given due attention is now being used on one of the dredges of the Conrey Placer Mining Co., and has been entirely successful and satisfactory in operation with a 550-h.p. digging motor, which I believe is the largest digging motor on any elevator type gold dredge in operation today anywhere.

In order to keep down the size of the liquid rheostat for this work, it is practically necessary to provide some means of artificial cooling for the electrolyte. Usually this is accomplished by circulating cooling water through the coils in the rheostat tank. On the Natomas rheostat the mistake was made of pumping water from the pond in which the dredge floats through these cooling coils. Due to the operation of the dredge this pond water is usually pretty muddy, and often carries a large percentage of solids in the shape of silt. At Natoma this silt coated the inside of the cooling pipes, thus reducing their effectiveness and eventually clogging them up, necessitating a shut-down while they were blown out with compressed air. Shut-downs on a dredge costs money, because to realize the greatest return on the investment, the dredge must be digging all the time. Therefore this feature made the Natomas rheostat undesirable. At the

Conrey Placer Mining Company's property, the cooling system consists of a series of pipe coils immersed in the pond, and the electrolyte is pumped from the rheostat tank through the coils and back again, instead of pumping pond water up to the tank and through coils installed therein. There has never been a shut-down on the Conrey dredge due to the rheostat or its cooling system. The motion of the dredge in the pond is sufficient to keep silt from settling on the cooling coils.

Another point that was overlooked on the Natomas installation was the fact that dredges swing, and often rock considerably. This causes the electrolyte to splash out of the rheostat. Usually such loss by splashing was replaced by pouring in additional water, but this of course changed the density of the electrolyte and caused the operators some trouble. On the Conrey rheostat baffle plates and enclosing covers were supplied, which effectually prevented any splash.

Another trouble that was experienced at Natoma was that, due to deficiencies in the cooling system mentioned above, the electrolyte very often attained a very high temperature during hard work, which caused excessive evaporation. Under certain conditions this evaporation was so great that the annoyance and expense of bringing the amount of fresh replacing water required on to the dredge and filling the rheostat was considerable. This trouble has been obviated at the Conrey installation by having an adequate cooling system.

All in all, it may be said that for large digging motors of say 350 h.p. and up, the liquid rheostat makes an ideal method of control, provided the rheostat is of adequate mechanical construction for the service and is provided with a proper and sufficient cooling system. Both liquid rheostat and magnet switch control may be arranged to give the same advantages as to protection against acceleration at too high a rate and against excessive overload due to sudden changes in speed.

It will probably be gathered from the above remarks that the successful application of electrical apparatus to gold dredging operations depends on a multiplicity of details, each of which may be of comparatively minor importance in itself, and this is true. With the areas that are now still available for dredging, a multitude of small economies must be practised in order to make the process commercially successful. When it is considered that many dredges dig for about four to five cents per cu. yd. and that the gold contents of the ground often run as low as seven cents per cu. yd., it can readily be seen that a matter of one cent econ-

omy or waste may make or break the concern doing the dredging. Therefore maintenance deserves consideration. But most of all, freedom from shut-downs is of prime importance. The dredge cannot make any money while it is not digging; but, interest, not only on the money invested in the dredge, but on the money invested on the purchase price of the land that is being dredged, goes on just the same, and therefore shut-downs must be avoided at any reasonable cost, and this should be particularly borne in mind in the selection and application of the electrical apparatus and its control.

A digging motor that may be of sufficient capacity, but cannot be adequately controlled, may break a bucket chain and put the dredge out of business for 24 hours. Ordinarily, dredge operators figure on operating 24 hours a day 365 days a year and a fair average is to expect the dredge to be actually performing its operations for 95 per cent of the total time.

On account of the high load factor, and on account of the comparative uniformity of a large percentage of the load, as well as on account of the comparatively large blocks in which the power is purchased, dredges make a particularly attractive load for hydro-electric central stations, and a few figures as to the power consumption of dredges may be of interest in this connection.

Moderate size dredges with buckets of about 5 to 7.5 cu. ft. capacity will handle from 60,000 to 100,000 yards per month, at a power consumption from $1\frac{1}{4}$ to $1\frac{3}{4}$ kw-hr. per cu. yd.

Larger dredges with buckets up to 15 cu. ft. capacity will dig from 125,000 to 250,000 cu. yd. per month, and will take from 1 to 1 1/2 kw-hr. per cu. yd.

The very large dredge of the Conrey Placer Mining Co. mentioned above, which has buckets of 17 cu. ft. capacity (I believe the largest in the world) has handled 520 cu. yd. of material per running hour. Including delays, this means 325,000 cu. yds. per month. Handling material (heavier than usual) weighing 3000 lb. per cu. yd. its power consumption was 1.28 kw-hr. per cu. yd.

The above figures are total power taken by the dredge for all purposes. The power taken by the digging motor is about 40 per cent, on an all day average, of the total power. From such test results as are available the power for digging seems about proportional to the yardage dug, *i. e.* the kilowatt-hours are proportional to the yardage handled times the number of hours during which it was dug.

Discussion on "Traffic Studies in Automatic-Switchboard Telephone Systems" (Campbell) and "A Comparison of the Telegraph with the Telephone as a Means of Communication in Steam Railroad Operation" (Clapp), New York, March 13, 1914. (See Proceedings for March, 1914.)

(Subject to final revision for the Transactions.)

William Maver, Jr.: I think it may be safely stated that if the telephone had been invented before the telegraph, and had been in use on railroads for train dispatching and the transmission of messages, up to the limit of distance of which it is capable, there would have been very little disposition on the part of railroad managers to displace the telephone by the telegraph, but when the telephone appeared the telegraph was well established on railroads, and its small cost and simplicity have served to give it the stability in railroad service that it has acquired.

The question of the more extended use of the telephone on railroads was under discussion before the Association of Railway Telegraph Superintendents at the Annual Convention in Wilmington, N.C., in 1899, and the chairman of the convention expressed the views of the Association when he said that the railroads as a general thing do not earn large dividends, and they do not care to spend much money on telephone lines. Although the subject of the use of the telephone for train dispatching was mooted in 1899, it was not until 1907 that its use for this purpose on a large scale began, and its employment in this service imperatively demanded the development of means for rendering it practically available, which demand was met by the introduction of selective ringing.

I think the idea prevails that iron has been quite largely displaced by copper wire for telegraph purposes, and that when iron is used in new work it is to give strength to the line. One important claim for the employment of copper wire in telegraphy in addition to its superiority electrically has been that when iron, by reason of corrosion, has become valueless, copper wire still has high intrinsic value as junk.

My experience on frequent occasions when I have had the option of using the telegraph or the telephone over distances ranging from 200 to 1000 miles has been quite favorable to the telegraph as a means of quick, reliable and intelligent communication between expert operators, chiefly due to an uncertainty as to certain words in telephone conversations, which frequently called for repetition. My observation of the operation of the telephone in some cases seems to indicate that when it is used regularly for questions and answers, the purport of which is generally understood by both speakers, conversation is easy. I have noticed this particularly in cases where the telephone is used as a means of communication between different sections of large manufacturing plants, where illiterate

workmen exchange information freely concerning the work in which they are engaged. When, however, subjects foreign to this work are broached to them by telephone, they are often at sea. While it is true that Mr. Clapp quite properly stipulates a high factor of transmission efficiency for the telephone circuits for this railroad service, I believe that some, at least of the success of this service between dispatchers, station agents and conductors may be due to their familiarity with the nature of the subject discussed, although, of course the precaution of spelling out the words of train orders, letter by letter, and repeating back the order to the dispatcher, is almost a sure preventive of error.

The fact that telegraph operators require months or years to become proficient is a great disadvantage of the telegraph as compared with the telephone, and the further fact that the labor element utilizes this condition to enforce its demands has, no doubt, been an important factor in forwarding the employment of the telephone for the movement of railroad trains.

Mr. Clapp makes the point that the telephone operator at a station cannot hear what is passing on the line until he cuts in, whereas the telegraph operator can hear everything. Seemingly, there is nothing to prevent the railroad telephone operator from cutting in at times from curiosity. Again, there have been cases in which it was important that the telegraph operator had heard the despatcher's messages to other stations.

The point brought out relative to the time gained by using the telephone in the movement of trains and in other directions, and the consequent saving in the pay-rolls of train crews, as well as the savings due to the displacement of expensive telegraph operators by less expensive telephone operators in many places, is a strong one, although the aggregate saving thus far does not appear to be great in the specific cases discussed by Mr. Clapp.

The change from the telegraph to the telephone in railroad service is quite a radical one, and has to face the condition that the telephone, like the telegraph, is not directly a revenue producer for the railroad companies, and hence does not always receive the recognition that its importance in the actual operation of the railroad system warrants. Considering, however, the fact that it is only within the past two years that any railroad officials have had the temerity to authorize the substitution of the telephone for the telegraph as a means of communication in steam railroad operation, the progress thus far made in that direction is really noteworthy.

William E. Harkness: The use of the telephone in the transaction of railroad business will be greatly increased in the future, and in many cases it will supersede the telegraph. There are, however, certain classes of railway communications which can be handled more economically by telegraph, so that we need not anticipate the complete elimination of the telegraph

as a means of communication. Whether telegraph transmission in the future is to be performed manually or by machine remains to be determined, but this phase of the situation is at present receiving considerable attention.

Mr. Clapp has given figures covering the average costs of line construction and station equipment on single or double track railroads. The amount covering station equipment may be increased to as high as $200 per station on multi-track trunk lines under complete telephone operation where the number of lines entering a way station varies from five to ten. Roads of this class are, however, few.

It is interesting to note that the annual saving in overtime by the use of the telephone on the one division mentioned amounts to 24 per cent on the investment, also that the saving given does not include the saving in time of motive power nor the saving in coal consumption, which are two of many expenses which are indirectly affected. Unfortunately, these savings cannot be calculated in advance when presenting the advantages of the telephone to the railroad management.

It has been found that the train dispatcher operating by telephone is under less strain than one operating by telegraph, and can handle practically double the amount of work he has been handling by telegraph. This in some cases has resulted in the extending of his district, as mentioned by Mr. Clapp. The savings in salaries alone in such a case will approximate $5,000 annually, which is equivalent to 25 per cent on the first cost of the telephone circuit over the two districts covered.

While the cost of telephone line construction is nearly double that of the corresponding class of telegraph construction, it must be remembered that the facilities for communication have been more than doubled. In the first place, the speed of transmission has been increased. The average railroad Morse operator does not send over 25 to 30 words per minute, whereas by telephone the same man will transmit at the rate of 50 to 75 words per minute, the latter rate being in excess of the maximum manual Morse record. One factor having a bearing on this matter, which differs from what of a commercial basis, is the greater length of railway messages.

Secondly, in addition to the two wires being used for telephone conversation, they provide an additional telegraph circuit at an expense of not over $100 for auxiliary equipment for simplexing the circuit: or, if two parallel telephone circuits are available a third or phantom telephone circuit can be secured capable of good commercial transmission for distances up to 500 miles at an expense of approximately $500. In one case where this has been done, a saving of $100 per month has been made in long distance tolls at one terminal alone, and no value placed on the time saved or increased use of the service.

The telephone for some time to come cannot compete with the telegraph in handling messages over distances of 1000 miles

or more. It is believed that the relation between long and short haul traffic will be approximately the same on railroad and commercial circuits, so that it would seem advisable to study the traffic handled before proceeding with the construction of long telephone lines.

While at present on the average railroad the telegraph is more flexible from the standpoint of additional facilities and the ease with which circuits can be patched in case of emergency, this condition will gradually change as the number of telephone circuits is increased on each railroad. It is not anticipated however, that the telephone will be able to compete with the telegraph when it comes to making up long roundabout circuits to reach distant points. For the average division, however, the same flexibility can be obtained by the use of adjacent circuits or an interchange of facilities by connecting railroads.

It may be well to state here that the success of the telephone for train dispatching depends not upon telephone equipment, but upon the means of selectively calling the individual stations.

It is of interest to note that the difference in time taken by operators to answer a telegraph sounder call and a selective telephone call has in some cases been so pronounced as to occasion the installation of telegraph selectors on some railroads to improve the telegraph service. In fact, there has been a marked revival of selective telegraph calling in both railroad and commercial service.

It has been stated that the use of the telephone for message service demands heavy traffic. This is true when a supervising operator is employed to do the calling of stations as described, but where the circuit is arranged so that any station can call any other station the telephone is particularly adapted for lines carrying light traffic, as for instance, the branch lines running from the main trunk line.

With regard to the labor situation, the fact that a man is an operator is secondary to the fact that he is a railroad man, and there have been very few cases where employees have lost their positions on railroads because they were telegraph operators, and replaced by telephone operators. The railroads, however, have a larger field from which to select their employees, and they are able, therefore, to select a better class of employees than they have had heretofore.

The telegraph departments of the railroads are not earning departments, and therefore have not been given the consideration, that other departments are given when it comes to spending money. The railroad is practically inoperative without the telegraph or telephone departments, and sooner or later more consideration will be given to them.

R. N. Hill: The implied conclusions in Mr. Clapp's paper that the telephone has a sufficient margin of merit over the telegraph as a medium for the transmission of intelligence in railroad operation to warrant its somewhat greater cost, seems

to be borne out by practise. We note, however, that in the comparison of costs of inside and outside plant, the facilities provided by a single telephone circuit composed of two No. 8 gage copper wires, have been compared directly with the facilities provided by one iron telegraph wire working duplex or quadruplex, and it seems that it would only be fair to recognize the fact that one pair of telephone wires is capable of supplying a telegraph circuit in addition to the telephone circuit, and that this telegraph circuit may be duplexed or quadruplexed. Also, if there are two similar pairs of wires on a pole, properly transposed, we may obtain from them not only a train dispatching and message circuit, but we may in addition obtain a third telephone circuit and a telegraph circuit; in other words, four circuits from the four wires. The cost of obtaining the additional telephone and telegraph circuit is only nominal.

Therefore, it would be more nearly fair to compare, as far as outside plant is concerned, the cost of one No. 9 A. W. G. wire with the cost of one No. 8 B. W. G. iron wire. On this basis the telephone will appear much more favorably in regard to initial cost.

I have noticed further, that the telephone circuit which has been especially designed for use in the railroad field has been referred to as the co-called "booster," and so that there will be no misunderstanding it would be well to emphasize the fact that it is only so called. It might better be called a "conservation " circuit, for in fact the gain in transmission which is effected, which in amount is in the neighborhood of four miles of standard cable, is due solely to the fact that we eliminate the dead loss which occurs in the ordinary telephone circuit by, so to speak, "talking out" through the receiver at that station, and receiving through the secondary of the induction coil. In still other and more general terms, it delivers to the line when transmitting more nearly all of the energy which the transmitting element is capable of producing, and at the receiving station it uses a larger percentage of the energy available in producing the necessary effect in the receiving instrument.

I gather from the statement regarding the use of booths at frequent intervals along the right of way for use in case of emergencies, that it is the usual practise to run a separate pair of wires to which these stations are connected, and to rely on a switching arrangement at an adjacent station at which there is an operator to connect the party to the train line. I am wondering if the intent of this arrangement would be to free the train wires of the load of a multiplicity of stations which are not used except at rare intervals. If so, it would seem more economical and the same result could usually be accomplished by the use of a reliable automatic cut-out switch, either operated by the closure of the door of the booth, or from the hasp of the padlock, to insure that the sets were disconnected from the line when not in use. I understand this is quite common practise with a number of the railroads.

D. P. Grace: Mr. Campbell's paper describes the apparatus for recording the time on trunk lines, and that is particularly applicable in automatic exchanges, but I think it might be of considerable use in manual exchanges.

Regarding Mr. Clapp's paper on the advantages of the telephone and telegraph, the most interesting thing to consider, perhaps, is that, in a measure, the dispatching circuit is an automatic system, in that the supervising operator or dispatcher uses the automatic mechanism for calling the operators along the line. As time goes on, it will be interesting to know how much more use is made of automatic apparatus in the general extending of the telephone system that Mr. Clapp predicts. There is a possibility that the automatic apparatus may be used at the terminals as well as in the dispatching along the line.

Mr. Clapp speaks of the delicacy of telephone apparatus and the increased cost of maintenance over telegraph apparatus. Now, it is true that telephone apparatus as placed in the hands of the subscriber along the line is, as a rule, delicate. The telegraph apparatus, on the other hand, is much stronger. Apparatus to be supplied for a telegraph line, or a telephone line, especially on a railroad, should be very substantially built, and if care is given to designing, I think much of the present maintenance charge could be eliminated.

In many railroad systems where telephone circuits have been used for message purposes, there has been a great deal of trouble due to poor transmission. This has most generally been traced to the lack of knowledge on the part of railroad telegraph people in the operation of these circuits. They have assumed that they could be used much the same as telegraph lines, and have connected into the circuit many miles of rubber covered wire and iron wire, and have even run these wires through many private branch exchange switchboards, the result being that the transmission was very poor. Wherever there is an extended telephone system along a railroad, there should be by all means a thoroughly competent telephone transmission engineer who can lay out the circuits and see that they are properly connected, so that good transmission will result.

The recent storm has shown the susceptibility of the overhead wire plant to serious damage and interruption of service. Unquestionably, this part of the plant, both among the railroad companies and the telephone companies, must be improved in the near future; but whether it is going to be a case of universal installation of conduits or steel poles or concrete pole lines, is yet to be determined.

Great economies would be possible in the handling of communications, in the handling of railroad trains throughout the country, if there could be some sort of combination or co-operation between the railroad companies and the telegraph and telephone companies. It is easy to see that one conduit line along the railroad tracks between the important cities of the country

would furnish means of communication for all telephone messages and telegraph messages, train dispatching, and the signal line service. If we are looking for economies in the handling of communications, I think that is one very fruitful field that is open to us.

John B. Taylor: One point that I want to raise is the relative ability of the telegraph and the telephone circuits to withstand disturbances from power lines. I ask if in making reply the author will express some opinion upon this subject as well as upon the relative ability of the two systems to continue service through different atmospheric and wet weather conditions.

In some respects the telegraph has the advantage here, in that it is less sensitive to the extraneous currents, and in other respects the telephone seems to have the advantage, in that there is no definite current above or below which the instrument will operate or become inoperative. The transmitted current may be very small, and still be a good recognizable speech current, while in the telegraph line, if it becomes small, it may entirely fail to actuate the instrument.

W. Lee Campbell: I want especially to call your attention to Mr. Clapp's suggestion that the use of the telephone in railroad service may be extended very much further than most railroad telegraph engineers seem to have contemplated up to date, by the railroads operating their own telephone plants at their terminal headquarters. I know of at least one large railroad which is now commencing this plan, viz: it is buying plants to install at its terminal and division headquarters, and is arranging so that any official, by calling the operator in charge of the message line, can talk direct to any station along the railroad line, and, vice versa, any official who may be out along the line at any station may signal the operator at headquarters and have her call the local official desired and connect the two together. This is something which is only possible, as a rule, where the railroad owns its own plants, because the public telephone companies which rent telephone service object to having any privately owned lines or equipment connected to their systems. I believe there is going to be a very large development along this line, and I believe that it will be a very great factor in converting the telegraph engineers and other railroad officials to the use of the telephone in the place of the telegraph.

M. H. Clapp: Referring to Mr. Maver's statement, in stating as a disadvantage the slowness of the telegraph when discussing a subject over a wire, I imagine that this is largely due to the way one has been trained. I have never discussed many subjects at length over the telegraph, however I have discussed very satisfactorily many matters over the telephone for long distances. I have always had the impression that the telephone provides a quicker method than the telegraph.

As to the matter of operators cutting in on the circuit, I did not mean to imply they could not cut in and listen on the tele-

phone circuit. The chances are, though, that they do not do this as a general thing, because they cannot attend to other duties if they are cut in on the circuit continuously; in the case of telegraph instrument, however, they can listen from different points in the room while employed at other work.

As to the matter of saving, I spoke of $100 a month, but I did not mean to imply that this was the only saving; it was given only as an illustration of possible savings. Unfortunately, a great many of the savings made possible by the use of the telephone on a railroad are more or less intangible and hard to express in figures. This $200 I mentioned is an illustration of the tangible saving which we figured out in a special case.

Referring to Mr. Harkness's statement in the matter of flexibility of the telegraph over the telephone, I had more in mind circuitous routings rather than any condition on the division. I appreciate very thoroughly that, by having a large number, or a reasonable number, of telephone circuits on a division, the system can be made practically as flexible as the telegraph.

I also appreciate that selectors have been used very successfully on telegraph circuits. However, they do not appear to be so generally in use—at least it would seem that the telephone had so many advantages over a telegraph circuit with selectors, that their use in connection with the telegraph has not been considered except in a few cases.

Referring to Mr. Hill's statement, comparing No. 9 copper with No. 8 iron, I appreciate that possibly I did not carry that comparison to a logical conclusion when considering the telegraph superimposed upon the telephone circuit. In my reference to the necessity of a special telephone circuit for the use of employees along the line, I had more in mind, this: Where the booths or cabinets in which telephones are placed are being used very frequently, and are stationed every half mile or so, I do not believe it good practise to provide means (even with a switch) of cutting in a telephone on a dispatching circuit. It would no doubt be better to provide separate circuits and terminate the circuits in various private branch exchanges along the line.

Referring to the use of the automatic system on the railroads, I believe that it is entirely practicable, especially in shops and terminals, where the number of telephones that do not need outside connection is large. There is one disadvantage, as I see it, however, in placing the automatic system in general use on the railroad—it is pretty hard to arrange a plan for connecting the long-distance lines to the automatic line.

Relative to power line disturbances affecting the telegraph and telephone, it has been my experience that power lines, electric light lines for example, affect the telephone a great deal more than they do the telegraph. In some cases it requires special study in order to avoid the inductive disturbances.

W. Lee Campbell (by letter): Mr. Clapp infers in his response to the discussion of his very interesting paper that there is

some difficulty in the way of connecting automatic intercommunicating systems installed in railway terminal headquarters with long-distance telephone lines, or railroad message telephone circuits. I am somewhat at a loss to understand whether Mr. Clapp meant by this that the Bell Company, heretofore, has objected to connections between its long-distance lines and either automatic or manual switchboards owned by others, or whether, not being thoroughly familiar with automatic apparatus, he is under the impression that it is more difficult to connect it to long-distance lines or message lines than it is to connect manual switchboards to such lines. Since some members of the Institute may place the latter construction on his remark, I wish, in justice to the manufacturers and users of automatic switchboards, to make it perfectly clear, that such switchboards can be and have been, for many years, connected to long-distance lines just as readily as manual switchboards have been. Calls from automatic switchboards to long-distance lines and vice versa are made by the thousands every day.

Donald McNicol (by letter): In view of the title selected for Mr. Clapp's paper, I take it, that, in the main, its scope is intended to include only a comparison of the telegraph with the telephone as a means of dispatching railroad trains, and as a medium of communication between railroad officials and operatives for the purposes of train operation.

The extensive employment of the telephone for the purposes cited, during the past eight or nine years, furnishes conclusive evidence that the telephone method more satisfactorily meets general railway requirements.

The points I wish to touch upon relate to the so-called "message" circuits, and to the efficient operation and maintenance of telegraph lines and equipment, with the object in view of increasing the usefulness of the telegraph.

It is quite possible that the general application of the telephone to take care of the service for which it is best adapted, has diverted attention from the possibilities in the way of increased efficiency of the telegraph.

It is stated in the paper that telegraph operators are scarcer now than formerly, and that the grade of men in this service is below that of the men engaged in the work a few years ago. My understanding is that the available supply of telegraphers has been, during recent years, considerably above the demand, and so far as ability is concerned, it is well known that the average telegrapher today can handle at least 25 per cent more messages per hour than were handled by the average telegrapher of a decade or two ago. It is further stated in the paper that the opportunities which the present-day telegrapher has to enter other fields of activity are much more frequent than 20 or 30 years ago. With reference to the situation here presented, I believe that it is very rarely now, that a telegrapher has an opportunity to get into any other electrical industry, due to the fact that speciali-

zation has rendered him unfit for any but the very low salaried places, such as " helper " or as student, and also to the fact that universities and colleges are turning out thousands of trained applicants for positions in the electrical field. Twenty years ago the head of most electrical enterprises of any importance was an ex-telegrapher, and the telegraph was the most prolific school of engineering. While the present outlook is rather forbidding to the telegrapher, it is very favorable to the telegraph; as it is now possible permanently to avail of the services of the brightest men who enter the service—those who formerly left it after becoming good electricians.

It is also stated that the number of messages that can be handled on a telephone message-circuit will average twice the number that can be handled by telegraph between the same offices. My opinion is that the reverse of this would be nearer correct—even where plain language messages are concerned. In the transmission of code telegrams, telephone handling is practically out of the question. A first-class telegrapher can handle seventy telegrams per hour all day, without hardship, on circuits practically unlimited in length. Telephone message work that I have seen done on comparatively short circuits and under very favorable circumstances, fell far below this figure in performance.

Again, it is stated that as compared with the telegraph, the telephone is a great time-saver, due to the fact that a dispatcher can transmit orders faster by telephone. It is my impression that where train orders are copied by pencil or stylus, the dispatcher generally can transmit by telegraph considerably faster than most operators can form copy sufficiently legible for trainmen to read. This brings to notice the fact that the speed of transmission in either case is determined by the speed at which the person receiving the order can write it down legibly. Undoubtedly a skilled telegrapher can write more rapidly than a trainmen or an untrained clerk. These considerations emphasize the fact that the alleged speed of the telephone over the telegraph where written messages or orders are concerned, is of no evident advantage.

Certainly, the telephone is a more satisfactory medium for carrying on short-distance conversations, especially between non-telegraphers, and the personal contact through the agency of the voice aids materially in limiting the discord resulting from misunderstanding of intent and attitude, which seems to be inseparable from the activities of train operation.

The paper states that under certain conditions the telegraph circuit is susceptible to disturbances to a greater degree than is the telephone. I ask Mr. Clapp if in this case a metallic circuit telephone line is being compared with a grounded circuit telegraph line.

In recounting the " disadvantages " of the telephone, I see no mention made of the fact that where telephones are used for train wire work, the operator has to remain at his desk with the

receiver to his ear in order to be informed of what is going on, while with telegraph operation, the operator may keep in touch with what is passing over the wire while attending to other duties, and without having to remain near the instrument.

Mr. Clapp says that except in very few cases the telegraph lines and equipment on railroads are not maintained at as high a degree of efficiency as are the telephone wires and apparatus. It is also stated that " the telegraph will probably continue to handle messages for the long distances, such as 500, 1000, or 1500 miles, for a considerable time to come." Those in close touch with the entire subject will undoubtedly agree that this latter conclusion is well founded, notwithstanding that a number of expensive attempts have been made to employ the telephone for this very purpose.

With reference to careless maintenance of telegraph lines and apparatus, it is my belief that herein are great possibilities for betterment, involving a reduced cost per message handled and a faster service. The railroad companies have in many instances availed unstintingly of expert telephone advice, in which they have been industriously assisted by the telephone companies, while the telegraph, even for long-distance work, has been regarded as a necessary evil—something to be dispensed with, no matter what takes its place.

It occurs to me that where there are five million telegrams per year handled on one railroad, with little likelihood of the number per year decreasing as time goes on, the possibility of clipping off half a cent per message in the cost of handling, by increasing the efficiency of the telegraph, should prove an alluring prospect in these days of high aims.

DISCUSSION ON "OUTDOOR VS. INDOOR SUBSTATIONS" (MACOMBER), "OUTDOOR SUBSTATIONS IN NEW ENGLAND" (HUNT), "INDOOR AND OUTDOOR SUBSTATIONS IN PENNSYLVANIA" (FULLERTON) AND "OUTDOOR SUBSTATIONS IN THE MIDDLE WEST" (PERRY). NEW YORK, FEBRUARY 25, 1914. (SEE PROCEEDINGS FOR FEBRUARY, 1914.)

(Subject to final revision for the Transactions.)

A. H. Kruesi: The time has passed for the discussion of the design of outdoor stations, and we must get down to the results of experience. The difference in cost generally between an indoor and an outdoor substation, taking buildings, equipment and steel structures, wiring, installation, etc., all into account, is generally not very large.

Mr. Hunt states that for the case he describes the difference is only about 11 per cent. That, I think, means that the outdoor substation should be restricted to comparatively small installations, like those, for example, which serve a single factory or industry. I think that for a substation which might cost anywhere from $20,000 to $50,000, a saving of $2000 to $5000 is altogether trifling, compared with the continuity of service which a city has the right to demand of a public service company, and that for such a small saving one would not be warranted in going to the outdoor construction if it can be shown that the risk of interruption due to the outdoor location of the apparatus is materially greater.

Two of these papers show photographs of outdoor stations for industrial plants using steel towers with the transformers placed on platforms on the towers. That makes the towers more expensive, due to the dead load, and the wind load, and I wonder if the transformers are put upon the platform as a matter of habit, because we have been hanging transformers on poles, or whether any real good is accomplished by having them up in the air. It costs more money, and in an emergency such as a burnout of a transformer it will require more time and money to take the defective transformer down and put a new one in its place.

A. R. Smith: The outdoor station is now some years old, and there are many of various capacities in existence, apparently giving satisfaction. The relative merits of the two types have frequently been discussed in a general way. What we want now are some records of actual operating troubles in different climates.

The reason for the existence of the outdoor station is economy, and there is no doubt that in many cases economy has resulted from the adoption of the outdoor station. There is, likewise, no doubt that many have been deceived in believing that they economized in resorting to the outdoor design.

The writer believes that there is a field for outdoor stations, and that the small transformer station of any potential without oil switches or attendants, and the large transformer or switching station of 60,000 volts and above represent the two classes where economy in first cost can be shown. However, the saving in the

latter is largely a matter of the system of connections adopted.

There are many considerations as regards the choice between the indoor and outdoor station which have not been generally discussed and which the writer would like to suggest with the hope that further data will be forthcoming. In fact, engineers in general are uncertain as to which policy should be pursued, and more enlightenment on the subject will enable us to proceed along definite lines with much greater assurance.

Oil-cooled transformers. The capacity of an oil-cooled transformer is wholly dependent on the area of radiating surface and the rate of heat transmission per unit of surface. The temperature of the transformer case when setting in the sun may be from 15 to 20 deg. fahr. hotter than if protected from the sun's rays. If the temperature of the oil is 135 deg. fahr. and that of the case is 115 deg. fahr., the difference of 20 deg. gives the factor of heat transmission. Now, if the case were shaded, the difference would be from 35 to 40 deg. which means that the outdoor transformer has to be much larger.

It has been suggested that the transformer tanks be painted a light color to retard the heat absorption, and this should be effective; but the radiation of heat from the tank to the air is something like a ratio of 14 to 19 for light and dark colored surfaces, so that the net gain is a question.

The radiation is also directly affected by the velocity of air due to the convection currents caused by the heat emitted from the transformer. In the case of an outdoor transformer the height of the chimney effect is approximately the height of the transformer, as the heated air is immediately diffused after leaving the top of the transformer. On the other hand, the ventilation of an indoor transformer can be directed and controlled so that a uniform circulation on all sides is maintained and a chimney effect of two or three times the height of the transformer obtained. It may be argued that the relative costs of the two types of stations has been based on the manufacturer's costs of the two types of transformers; but the manufacturer has been obliged to use a factor of safety on indoor transformers much too high because so many transformers have been placed in buildings without any consideration for ventilation. Now, give the manufacturer a drawing showing a perfectly ventilated building for the transformer and then compare the costs of the indoor transformer with the outdoor transformer having more radiating surface or smaller copper and core losses; outdoor bushings; water tight covers; non-freezing oil, or the capitalization of the losses due to exciting idle transformers; heating coils, and the capitalization of losses in the same, and we will find a greater difference than anticipated.

Water-cooled transformers. Water-cooled transformers are better suited for outdoor service, but these too have objectionable features. First, the water has to be kept in circulation in all idle transformers every day that the temperature is below 32 deg. fahr., which entails a pumping expense, and extra valves and

drains are necessary so that no water is left standing in dead-end pipes when a transformer is removed in cold weather. Second, oil-drain piping has to be designed without pockets which might become filled with moisture of condensation and freeze, and all valves have to be kept in working order. Third, the circulation of water in an idle transformer has a tendency to keep the oil from freezing, but it might be necessary to arrange to use the warm water obtained from the transformers in operation and then, at the best, this is very ineffective as the water coils are at the top of the transformer and all heat transmitted to the oil at the bottom is by conduction and not by convection.

In general, the heat produced by the transformers is wasted in winter when it is most needed, and in summer, when it is difficult to dispose of the heat, the transformers are located in the warmest place—in the sun.

Lightning arresters. With an efficient electrolyte the film dissolution on the cones is very rapid when the temperature exceeds 100 deg. fahr. To insulate the arrest r tanks from the sun's rays is objectionable because it confines the heat if the arrester is discharging frequently. It has therefore occasionally been necessary to protect the arrester by means of a sunshade.

Oil switches. During rainy weather short-circuits are most prevalent, and it is often advisable to inspect the oil switch contacts after rupturing a severe short-circuit. In the case of the outdoor oil switch, this can only be done in wet weather by removing the switch to the repair shed, because of the possibility of permitting moisture to enter the tanks.

It has long been acknowledged in the design of steam plants that apparatus located in hot, wet or inaccessible places does not get the attention from the operator that it should. Now, how much attention is going to be given to the oil switch operating mechanism during stormy weather? Will not repairs and inspection be postponed for more favorable weather? What is the possibility of the switch failing to open due to this lack of attention and postponement of repairs? What is the life of a switch and consequent depreciation of an outdoor switch as compared with an indoor switch, and what does it cost to provide facilities for transporting the oil switch to the repair shop upon the least provocation?

In some outdoor installations it has been necessary to provide by-pass disconnecting switches so that the switch could be left in disuse until a favorable opportunity presented itself for repairs.

High-tension wiring. Buses and disconnecting switches are the safest to locate out of doors, and they really require the most building space. A semi-outdoor station is possible and economical with certain wiring connections, where the apparatus is protected by a moderate size building, and all of the wiring located out of doors.

Fire risk. It is frequently claimed that the outdoor station is a better fire risk than the indoor station; but this may or may

not be true. The spacing between conductors out of doors may be considerably greater, but at least 50 per cent greater spacing is necessary to obtain the same factor of safety, because of the rain and the wind which will start an arc sooner and carry it farther. Then there is the transformer fire risk. We can readily imagine the resulting damage if a transformer should get on fire adjacent to a steel tower, the failure of which might result in the collapse of the entire steel structure of bridges so often employed.

Facility of making additions. The outdoor station can readily be added to or changed; but it cannot be readily housed in if the outdoor scheme is found unsuited for the climatic conditions. Furthermore, if all of the money is invested in the apparatus, the cost of replacing it due to obsolescence, inadequacy or depreciation is proportionally increased. The life of a building is usually considered to be at least twice that of the apparatus.

General considerations. The maintenance of the outdoor station structures should not be materially different from the building structure, as the steel towers should be painted, provided the wiring is arranged to make painting possible, and the walks, foundations, fences, repair shop, and operating house kept in repair. The cost of maintenance of the outside apparatus will probably be more than the inside apparatus.

In cold climates there are the snowfalls and drifts to contend with, which means extensive shoveling of paths, and the clearing of the tracks and turn-tables of ice. And during electrical storms, all of the apparatus is exposed to a direct stroke of lightning, as choke coils cannot conveniently be arranged always to direct the lightning to the arresters.

These objections are set forth, not with a view to discourage the use of outdoor stations, but to show that the saving of a $25,000 or $50,000 building does not necessarily represent the net saving, and that the resulting saving is not always sufficient to warrant the adoption of the outdoor station, if reliability is to be sacrificed or maintenance increased.

Roy E. Argersinger: We must see a very large saving in order to make the outdoor substation worth while, as I believe the danger we run into ought to be very seriously considered. For instance, if we get a bad storm, we are more likely to get trouble at that time than when the sun is shining, and we do not want to go out and pull the transformer apart when a heavy storm is raging. It is hard to get any one to work on the outdoor substations during such conditions. During the last week in our country we have had the thermometer down to 15 and 18 deg. below zero, and it is hard to get linemen to look at the line, to say nothing of the station, under such conditions.

H. B. Gear: It seems to me that the economic question whether or not the outdoor substation pays is very largely a question of determining the balance between the cost of the building and the cost of the rest of the equipment: In industrial substations running from 150 kw. to 1000 kw., the possibility of an outside

substation is just as likely to be fixed by local conditions as by the desirability of saving the cost of a building. In some manufacturing plants there is no available space for the placing of a substation. The equipment must be placed on poles in the public thoroughfare or installed in a vault, if the line is underground.

For the small r substations it is not entirely an economic question. The cost of the building, if a separate building is erected for the purpose, is apt to be as much or more than the cost of the equipment itself in the smaller sizes, and therefore anything in the way of an enclosing building becomes a considerable addition to the total investment.

As we pass up to the higher capacities, and where the outdoor installation becomes desirable, because of the fact that the service is supplied by very high voltages, the problem becomes a little different. The tremendous separation required for 66,000 volts, naturally suggests putting the apparatus outdoors rather than building a structure big enough to provide necessary clearances. In the case shown in one of the papers, the saving figured out is about 11 per cent. At lower voltages, and with large substations such as are found in metropolitan work, with several thousand kilowatts involved, the amount which may be saved is a much smaller percentage, since the potential regulators, the switchboard equipment and all the accessories required in distributing from a substation, as a matter of giving good service, must be placed indoors, and only the transformers and the switching equipment could go outdoors. In this class of installation, it will not often be found that a great deal can be saved by building an outdoor substation for the transformer equipment.

The point which is touched on in Mr. Perry's paper with regard to the use of outdoor substations in high-tension distribution is an important one. The ability to serve large areas by means of 33,000 volts, as is being done in Northern Illinois, in dependent largely upon the possibility of locating comparatively small substation equipment out of doors. There are numerous cases where transformers as small as 50 kw. are supplying towns along the route of the line in which it is possible to give fairly good service without anything but a platform and a little local construction. This would not be possible from an economic point of view, if it was necessary to construct a building and use the type of equipment which was considered necessary for a substation a decade ago. Outdoor construction may be applied in a variety of ways and has a very definite place in electric distribution.

W. S. Moody: The four papers that have been presented on outdoor transformer stations give a very good general review of a recent development in our art. It is not a radical improvement in the sense that it requires any great change in previous methods of designing apparatus, or any inventive ability on the part of the manufacturer, and yet, it does mark an important epoch

in electrical developments, which, I believe, will be more fully appreciated as the practise becomes more general.

As has been pointed out, the innovation in practise started purely on its economic showing. Both the manufacturer and the operator shrank a little from the idea at first, because it clearly increased the risk for both, but none of the various possible sources of trouble are really inherent and it only needed, therefore, some experience and a close and intelligent study of details to avoid them.

If I may be allowed, I will point out two respects in which the papers do not give an entirely correct idea as to how far this practise has progressed. It is stated that there is something like 300,000 kv-a. in outdoor transformers installed or contracted for. Those for whose design I am responsible alone amount to 25 per cent more than this figure, so it is fair to assume that the actual capacity of such transformers so far produced may be nearer 600,000 than 300,000.

The other incomplete impression given is as to the maximum size of units and installations. Units have already been built up to at least 7500 kv-a., and installations up to 50,000 kv-a.

The most important features to be cared for in an outdoor design (as far as our experience yet goes) are:

(a) Covers, joints around leads, man-holes, etc., must be thoroughly weather-proof. This not only means that they be rain-proof, but so completely sealed as to be water-tight when ice and snow build up and hold water over the joints.

(b) That the leads be made of such material and in such a manner as to be entirely unaffected by the weather.

(c) That the tanks be so ventilated that they will not take in rain or snow and yet may relieve themselves from moisture and gases.

(d) That idle units be heated sufficiently to avoid their being at a temperature lower than the atmosphere.

I want, in closing, to say a word of caution with reference to the needless use of outdoor installations. Some people are anxious to use the latest thing, whether it is best for their conditions or not. It should be borne in mind that however well the apparatus may be designed for outdoor service, it cannot be quite so safe or convenient when so installed as if it were protected from the weather, consequently the lower cost of installation and possibly a little less fire risk are the sole reasons for outdoor installation, yet I have seen such installations right beside large stations that had and probably always will have more than ample space for the transformers inside. In such cases considerable extra expense had to be incurred in carrying both high- and low-tension wiring, already inside of the building, out to the transformers and back. Such an installation made simply to be in style is certainly not good engineering.

Allen M. Rossman: Mr. Kruesi asked the reason for putting the transformers in various substations above the ground. With

reference to the substation shown in Mr. Perry's paper, there were two considerations which led to this design;—one was to keep the 33,000-volt wiring up out of the way; the other was to provide, within the structure, a housing for the low-tension (2300-volt) meters and switches and for an arc lighting transformer, if needed. Consequently, the whole substation is self-contained.

I might say, regarding the cost of this particular substation, that the structural steel as shown, together with the fuses, horn gaps, choke coils and disconnecting switches complete—the structural steel being galvanized—cost very little more than would a first-class 33,000-volt oil switch, and it is only by reason of this low first cost of substation that an extensive 33,000-volt distribution system supplying a large number of small scattered customers is possible.

J. C. Smith: We have had very little experience with the large outdoor type of substation around Montreal, and in other sections of Canada, probably because the use of an outdoor substation would involve the use of naturally cooled transformers. We could not use water-cooled transformers on account of the temperature conditions. For example, at our power plant, for the last four weeks the temperature has not risen above zero, so that you can imagine to take care of water-cooled transformers would be quite a difficult task. So that while we have done considerable calculating on the subject, the matter always resolves itself into the fact that it would be necessary to put in, at very considerable extra expense, means for protecting the apparatus from the cold, and we have not yet had enough confidence in the oil switches to feel that we could operate them successfully under these very severe climatic conditions.

P. W. Sothman: I think I will have to agree with Mr. Smith in his remarks on this matter, as to the reason why it was decided that Ontario was not the place for the outdoor substation. I think we would have had to spend more money for heating up the system, than for keeping it cool. In a general way I think the matter of outdoor substations should be dealt with on its merits. I think, without any question, there is a big field for the outdoor substation. On the other hand, I think there are many places where the outdoor substation is not the one which is needed. The comparison of cost, between the outdoor and indoor substation, may play, to a certain extent, some part in the matter, but I think, from the operating standpoint, we should be very careful to draw the line between saving a few per cent and then running a risk of destroying the necessary continuity of the service which is essential above all things.

When we look over the liabilities which a public service corporation assumes, when we look at the mistakes which have been made in certain sections of the country by the saving of a few cents, and thus weakening the guarantee of a fairly good service, due to not properly protecting the system, or some part of the

system, we soon come to the conclusion that such a policy is very bad engineering. I think the motto should be, first of all, continuous service, if possible, within commercial reason. If we are guided by this consideration, and in addition give proper attention to the climatic conditions, I think that will tell us where an outdoor substation should be built and where an indoor substation should be built. I think also we will see, to a certain extent, the combination some day of the indoor-outdoor substation even in big cities.

J. Edward Kearns: A careful analysis of this subject will resolve itself into two factors: first, that representing continuity of service, and second, the question of cost, including not only first cost but maintenance and depreciation.

With respect to continuity of service, the principal point, of course, is to be careful to select apparatus best suited for local conditions and that which will eliminate, as far as may be, all possibilities of shut-down. When we come to the question of first cost, a careful comparison has been made of several outdoor substations and indoor substations, which shows that the outdoor type is about 10 per cent to 15 per cent cheaper, in sizes of 2000 to 5000 kv-a. Now, perhaps, the main reason why the cost of the indoor substation exceeded that of the outdoor substation, has been due to the type of building and other architectural features brought into the construction of the building. I personally feel quite positive that if more of our smaller indoor substations were built with a very cheap sheet metal building, we would find that the general comparison would be about equal, particularly if we keep in mind the fact that it is always desirable to have an attendant when large outdoor substations of 10,000 to 20,000 kw. are installed, and, under these latter conditions, I believe it will be found that the general result will be very much in favor of the indoor type of substation.

Another important subject that has been brought out in the discussion, in addition to these two, is the question of climatic conditions, and large installations to date indicate that less trouble may be experienced with outdoor substations in southern climates than those in the northern or cooler climates, with the result that many operating companies in the North are not installing outdoor type substations but are considering instead a very cheaply housed substation.

K. C. Randall: The very pronounced increase in the reliability of apparatus in general, especially that which is involved in outdoor installations, has contributed immensely to the practicability of the outdoor station. Transformers and breakers have been simplified, strengthened and made more substantial and reliable, with more permanent factors of safety, so that now under nearly all conditions they can be looked upon as largely free from the need of attention.

As an economic problem, there is no doubt that good consideration is required to determine definitely the justification

of the outdoor station, or, so far as that is concerned, of the indoor station. It is also possible that fashion may have brought outdoor stations into being when the indoor station might have been better, but the same can be said of the indoor station. Probably there are few men with experience who can not recall instances where the outdoor station would have been a better proposition than the indoor station which was built.

Terminals for apparatus and station outlets are so thoroughly developed, that very little or no trouble is encountered from those of best design. These were the original stumbling blocks when the outdoor apparatus for heavy potentials was first undertaken. Terminals that will stand 300,000 volts in a 45 deg. precipitation of ⅛ in. per minute are in use and are entirely practicable. Terminals for all lower voltages and current ratings have been developed with equal success.

The first 100,000-volt transmission in this country, whose transformers were built under my direction, operated without lightning arresters entirely successfully with a grounded overhead line wire extending but a few miles from the stations where the transformers were installed. This was some years ago. There is no doubt that transformers of today are equally reliable, which means that the necessity for repair is remote. The same applies to switching apparatus and therefore, in general, the outdoor equipment is not likely to demand much attention.

Five years ago this subject was presented before the Institute, and it was then suggested that the outdoor station would have a place under some conditions but that no general rule could be stated for determining when the outdoor station would be justified. The four papers presented today have shown that there have been applications for an outdoor station which have been justified, for it is not reasonable to assume that all, or even many, having made these installations have been wrong in their judgment.

It is, therefore, gratifying to me to have this confirmation of the opinion then expressed. At that time many doubted, according to their discussion, and even today the same attitude would seem to prevail in some places, although the practicability and desirability of the outdoor station has been thoroughly confirmed.

Henson E. Bussey: We have quite a large number of outdoor substations. The capacities of these outdoor substations run from 20,000 to 30,000 kw., but it has always been an open question with me as to whether or not there was not a little bit of stampeding in building outdoor substations in our climate. A great many people seem to think that the South is a particularly good climate for outdoor substations. I do not think so, for the reason that very frequently we have rainfall at the rate of as much as three to four inches an hour, and at the same time extremely high winds, and if transformer tanks and switching tanks are not absolutely tight, then undoubtedly trouble

is going to develop. As to whether or not that trouble will develop, it is a question of simply waiting to see. It has not developed so far.

It seems to me that the relative advantage of outdoor versus indoor substations for any climate lies in the question of the first cost, as has been brought out, and in the reliability of operation. The question of the first cost is something which the companies which have been building these substations can very materially assist in settling. I would like to know whether or not the outdoor substations are really cheaper, considering the same class of installation, than the indoor. I very seriously doubt it. I know of one case of a 20,000-kw. outdoor substation—five of them, in fact, which were built on the same system, where the people who had charge of the building stated that it worked out in advance very much cheaper than would have been the case had they used indoor substations. After they had been built, I found that they worked out nearly fifty per cent in excess of the estimates, and now it is a question whether or not they are cheaper. It is safe to say that they could have built the indoor substation as cheap if not cheaper.

The character of the building is an important factor, but I am firmly convinced if we could get some data from the operating companies and the people who are constructing the buildings and substations that the point will be settled once for all.

E. A. Lof: One point that must be given considerable attention in connection with outdoor substations is the protection of the transformers, both from the extreme heat in summer and from the cold in winter. While the former can be readily obtained by providing sunshades, in certain instances very good results are obtained, as stated by one of the authors, by simply painting the tanks white.

It is, however, more difficult to provide for the cold winter temperatures, especially with water-cooled transformers. With the transformers in service there seems to be no danger of freezing, and for this reason the transformers should be connected to the circuit and thus energized even if they do not carry any load. Some sort of heating grids can also be readily provided in the bottom of the tanks. The main difficulty lies in the formation of moisture which takes place when the temperature of the transformer is allowed to fall below that of the surrounding air. This applies equally well to indoor transformers, and precautions must therefore always be taken to prevent this. Much may be accomplished either by reducing the water rate at times of cold weather, or by using the cooling water over and over again.

There are a number of other points which should be given consideration in the construction of the outdoor substation. The line wires should be securely anchored before entering the station structure, and no unnecessary strains should be permitted in the wires inside the structure. Consideration should

be given to deflections resulting from different pulls on the connections, and also to unequal settlement of supporting towers which may readily cause excessive stresses and insulator breakages, resulting in service interruptions. The spacing of all the conductors, as well as that of apparatus, should be liberal, but not excessive.

The transformers and switches should be placed on concrete foundations of a sufficient height to be clear of water, and the station should furthermore be well paved and drained around the apparatus. Transfer tracks with a truck will also be found very convenient when moving the apparatus. Cement walks should be laid on that portion of the ground where the operator is most apt to pass in his inspection trips and work about the place. The oil piping to the transformers and switches, and the water piping, if water-cooled transformers are provided, should be so arranged that connection can be made or broken for any unit without disturbing the operation of the other.

Farley Osgood: In New Jersey we have no outdoor type of substation as described in these papers. We do not get the isolated conditions in our territory, which warrant such an installation, and the service is so congested, and in New Jersey is coupled together with railway service, demanding so much continuous switching, that it is questionable if the outdoor type of substation left a good deal by itself would work with us. The New Jersey territory, generally speaking, is a well solidified field of operation, with a good many substations, not very far apart, and the demands of combined service require so much personal attendance, that it is very doubtful, except in developing the outskirts of the territory, if anything but the indoor type of station would be installed. Our problems are simple, because our voltage is 13,000.

Dugald C. Jackson: I want to express this proposition as one that runs through my mind—and I think it is pretty definitely fixed there—that in the case of large substations on which a great deal depends, reliability becomes a matter of the very greatest importance, and under these circumstances the cost of the building is so small a factor of the total investment cost for the distribution system, and converting apparatus and real estate, that the saving of 20 per cent, or even 50 per cent of the cost of the building alone may not be a factor to be considered, and consequently large substations, especially those serving cities, should ordinarily be housed under the very best conditions of fire-proof construction.

But there is a different condition to be considered, and that condition is well illustrated in Mr. Perry's paper, also in Mr. Fullerton's paper, and to some degree in Mr. Hunt's paper. It would be again illustrated if we had a paper from the Rocky Mountain region. There one has vast areas—the Rocky Mountain region is sparsely populated, the same is true of parts of the prairies of the Central West; and it is even true, in part, of

the state of Massachusetts, which, next to Rhode Island, is on the average the most populous state in the Union per square mile, yet there is a good part of Massachusetts in which the population is very sparse—this is also true of the states of New Hampshire, Vermont and Maine. In such sparsely populated territory, there is here and there a customer, who should be provided with power, or a small village, which should be provided with power, where, perhaps, in the past they had a small electric lighting plant of their own, but have been seeking better service afforded on a more favorable basis.

These needs of isolated individual customers and small villages of the Far West, of the Central Western praries, probably the South, and of New England, can be served by outdoor substations, or, perhaps, by what have been called outdoor-indoor substations. Mr. Fullerton describes the latter fully and admirably. The latter development is one which seems to me to possess great economic possibilities for electrical engineering, because it may aid in the making of another step toward putting power transmission into the same category of comprehensive usefulness and importance as transportation and the transmission of intelligence.

DISCUSSION ON SUB-COMMITTEE REPORT ON "PROBLEMS OF HIGH-TENSION TRANSMISSION LINES" (SOTHMAN AND OTHERS), AND "PRACTICAL OPERATION OF SUSPENSION INSULATORS" (BUCK), NEW YORK, FEBRUARY 26, 1914. (SEE PROCEEDINGS FOR FEBRUARY, 1914.)

(Subject to final revision for the Transactions.)

H. W. Buck: I want to corroborate what has been said in regard to the sag table. It is one of those engineering problems which are worked out in the office in accordance with certain theoretical laws which are apt to be more or less disregarded in the field. There are many such phases in engineering, and there are some good reasons for disregarding the exact science of such deductions in field work. A sag table is worked out usually for level country, with a few cases given as exceptions to apply to certain typical points on the line where the profile varies from level. With a line crew out in the mountains under severe stress of weather, working as best they may, possibly at low temperature and with high winds, it is absolutely impossible to get construction men to pay attention to such refinements as are usually given in sag table calculations.

The point of this is that we should not rely too much on theoretical data of this sort. We should give our instructions in such form and should make our designs with sufficient margin so that results can come within the scope of action of the average construction crew, and not make the operating success of a transmission line dependent upon the fulfilment of all of the exact theory exemplified in a sag table.

F. W. Peek, Jr.: It requires a certain energy concentration to rupture insulation, break down insulators, etc. Such energy concentration may result when sudden changes are made in the stored energy of the system. These sudden changes may result from internal conditions or by energy impressed from external sources, such as lightning. The results during such changes are called transients. In modern high-voltage engineering the term "transient" has become a common and important word.

In order that energy may be transmitted from one point to another point to be utilized as useful work, energy must be stored in the space surrounding the conductors, in two forms—dielectric and magnetic. Energy is stored in the dielectric circuit with increasing voltage and delivered back with decreasing voltage. Energy is stored in the magnetic circuit with increasing current and delivered back with decreasing current. With transients, as with all el ctrical phenomena, there are three constants with which the enginee must deal: with resistance, which causes the absorption of energy somewhat analogous to friction; with capacity and inductance, which act as energy storage reservoirs.

The energy stored in the magnetic field is

$$\frac{i^2 L}{2}$$

The energy stored in the dielectric field is

$$\frac{e^2 C}{2}$$

When the current is zero, all of the energy is stored in the dielectric.

If i is suddenly changed, after a given time the circuit gradually assumes a new e and i. The transient occurs between the initial and final values of i. During this time energy is transferred from one form to another at a given definite frequency called the natural period of the circuit:

$$f = \frac{1}{4 \pi \sqrt{LC}}$$

The resistance of the circuit acts as a damper and gradually dissipates this energy.

For example: suppose a switch is suddenly opened when all of the energy is stored magnetically. i is suddenly reduced to zero. The energy must be changed to dielectric energy or the voltage must first be increased to a sufficient extent to store this energy in the capacity; thus e becomes

$$\frac{e^2 C}{2} = \frac{e^2 L}{2}$$

$$e = i \sqrt{\frac{L}{C}} = i Z'$$

The term $\sqrt{\frac{L}{C}}$ thus acts somewhat as in impedance and for this reason is called "surge impedance." When energy changes from one form to another in this way at regular time intervals and no energy is transferred along the circuit, it is called a "free oscillation." The oscillation continues until the energy is dissipated by the resistance.

When an oscillation is impressed upon a circuit which has no definite relation to its natural period, it is called a "forced oscillation."

If electrical energy from some external source—such as lightning—is suddenly impressed upon a transmission circuit, it travels along the circuit with the velocity of light and it is called a "traveling wave." The energy stored magnetically is equal to the energy stored dielectrically. The traveling wave may thus be thought o as being made up of a voltage wave and a current wave in phase.

In a standing wave the voltage and current are at 90 deg. (and not in phase as in the traveling wave), as in this case no energy transfer takes place.

These various transient phenomena are all subject, to a certain extent, to calculation, but experimental work is necessary to

determine their cause and the means for their suppression. The effects may be quite different, depending upon the apparatus. For instance, low-voltage high-frequency forced oscillations may be impressed upon a circuit without damage, except in certain apparatus containing inductance and capacity, where very high local over-voltages may be built up. A single impulse of very steep wave front may be applied to an insulator The voltage of this impulse may be many times the 60-cycle puncture voltage of the insulator. Flash-over results. During the flash-over, which requires a very small but definite time to start, this insulator is strained and small local cracks may result. A sufficient number of these impulses will cause breakdown of the insulation. If two gaps of differently shaped electrodes are spaced so as to spark over at 100 kv. at 60 cycles, and these gaps are then placed in parallel and an impulse of steep wave front is applied, discharge will take place across one gap and not the other, even though the non sparking gap is greatly decreased in length. The voltage is high enough to spark over either gap. It therefore goes over the gap requiring the least time to rupture. It may be interesting to note that a traveling wave 1000 ft. (305 m.) long passes a given point on a transmission line in approximately one millionth of a second. It can be seen that the experimental problem is a difficult one.

From the protection standpoint, oscillations must be absorbed and dissipated by resistance or the wave front of traveling waves modified by the two other circuit constants.

Spectacular "high-frequency" tests blindly made on apparatus are barbarous. Tests of this sort should never be made unless thoroughly understood. Rupture does not take place at a lower voltage at high frequency (where heating does not result) but generally a higher voltage is required to accomplish the same destruction in the limited time. Damage results from the enormous local concentration of voltage.

Certain phenomena which always exist go unnoticed in engineering until the energy involved becomes great enough to make them problems. The turning-point may be quite sudden, and it often appears as if new and mysterious factors enter. Such, in a way, was the case of corona on transmission lines. Up to 80,000 volts or so the conductors were sufficiently large so that dielectric flux concentration was not great enough to cause rupture. In order to keep the same amount of copper and transmit greater energy, the voltages were increased. This increase of voltage was just sufficient to bring the dielectric flux density past the rupturing point. Corona phenomena changed from those of a few brush discharges at rough points on the conductors to complete breakdown of the air around the conductors. Corona thus became a problem, and the laws of corona loss were determined. A similar turning-point has just been passed in solid insulation. The insulation problem has changed from a mechanical problem to a problem of the dielectric circuit.

Charles E. Waddell: I am inclined to think a right-of-way easement is to be preferred to ownership in fee. Usually an easement is cheaper to acquire; and when containing a proviso for ample clearing of timber an easement will serve every purpose. The length of the span determines the width for timber clearance, and while the right-of-way strip may itself be of inconsiderable width it may be very necessary to clear high standing timber to quite a distance from the line, as high winds frequently blow the line far out of plane.

As to the question of grounded steel towers versus wooden supports, I confess that at the present state of the art I am leaning back toward wooden pole construction with wooden arms and non-grounded fittings. I have in mind a line where a steel tower line is paralleled by a wooden pole line, both 60,000 volts, from the same transformers. The wooden pole line is of standard, conventional crossarm construction, with pin type insulators The steel tower line is equipped with suspension insulators. The interruptions on the suspension insulator line have been too numerous to count, while the wooden pole line has yet to have its first interruption.

A point brought out by Mr. Buck is the question of line ballasting and the effect of swinging of insulators. It seems to me that it is desirable to suspend the insulators so that they have infinite latitude to swing with the line, making a hinge for that purpose, but that the movements across the line be restricted to the lost motion in the joints themselves. With a wind blowing across the line, the swinging is restricted to the individual span, —the line as a whole is not deflected outward. This prevents a wave starting that may ultimately end in the line rotating, with the result in some cases of wrapping the conductor around the ground wire.

I heartily agree with Mr. Buck as to the wisdom of using a number of small, single-piece, inexpensive disk insulators. I believe these are to be preferred to the use of the two-part insulator with its greater surface and greater first cost.

I cannot say that I agree with Mr. Buck on the subject of ballasting the line however. It seems to me it might be a very excellent desideratum where some emergency condition had to be met, but in designing new work I think that a lower voltage and larger wire, a more carefully graded line, and closer tower or pole spacing, would meet the same ends without introducing the added weight on structures and stresses on the insulators.

Reference was made in Mr. Brundige's paper to the fatigue of porcelain. I want to suggest that this fatigue, perhaps, is not due alone to the electrical stresses, but to a combination of electrical and mechanical stresses. The majority of insulators strung up and sustaining only their own weight successfully withstand laboratory test for flash-over and puncture. The same strings of insulators when placed on the line and supporting the weight of the conductor, which may be 1000 lb. (453 kg.) or

more, break down under a very slight rise in voltage. The only conclusion I have been able to reach in the matter is, that, due to some obscure phenomenon, the dielectric strength of the insulators is weakened, and that if the mechanical stresses were removed the insulation would in all probability be as high as when actually tested.

Of the types of conductor mentioned in the committee's report, the one that particularly appeals to me is the steel-cored aluminum. I built an experimental line of this material in 1910. The line was seven miles (11.3 km.) long and of three conductors, equivalent in carrying capacity to No. 0 copper. The wire had a breaking stress, I believe, of some 6000 lb. (2720 kg.), and an elastic limit of some 4000 lb. (1815 kg.). The cables were drawn with a dynamometer to about one-fourth the ultimate strength; approximately 1500 lb. (680 kg.) The topography of this particular line indicated that some such conductor was best suited to the particular need. The spans varied from approximately 200 ft. to 2400 ft. (61 to 730 m.).

I have had this line under critical and constant observation since it was built, and have no fault to find with it whatever. Due to bad judgment on my part, the wires were placed too close together, and the high winds have occasionally swung them together; and when the burn is sufficient to fuse the aluminum, it is found that the steel core sustains the strain, and further, that the aluminum under the stress unwraps and frays, making it easy to locate the place by observation from the ground.

Another reason for using it, a reason which I think is a good one, is that, assuming the life of the cable is short, say twenty years for example, the saving over the cost of copper for such lin is ten per cent to fifteen per cent; and if the line is completely destroyed within the twenty years, the material has justified its use.

Percy H. Thomas: The most important topic brought up it seems to me, is the matter of the so-called deterioration of porcelain. It has developed to a critical point during the last year in many different parts of the country and with many different kinds and makes of insulators. It has developed, sometimes, where it could not possibly be due to electrical causes; and sometimes it is an open question whether it is not due to electrical causes. The problem is to find out as quickly as possible what it is, and how to overcome it.

I think we can conclude that it is not due to the deterioration of porcelain *per se*, for, taking the worst cases of breakdown of insulators, there are many insulators which are, apparently, absolutely uninjured, or, in any which are injured, the material is good. It is, in my opinion, therefore not a deterioration of the porcelain *per se*. It is not always due to the presence of electrical potential. I think that in all probability a great deal of it is due to the processes of manufacture. When you consider that the material at one time is in a plastic state,

and that when it is burned it has to shrink into a semi-crystalline mass, keeping every portion intact, you can see that, during the forming, the pressing and the twisting it gets, somewhere on the inter'or there is a slight plane of separation formed. The edges may be daubed over and adhere, yet this fault will never be corrected. There may be enough good porcelain to hold the potential during the test, while the insulator is new, before the faults develop. I think the evidence of the general situation points to this conclusion.

You cannot blame the manufacturers for it, exactly, as they are doing the best they can, and there is no one manufacturer who has all the trouble; they all say they are having trouble, and it is a problem which we must work out with time, and we must find some way of detecting the bad insulators. That can partly be done by tests, but we need a few new tests.

If we can assume that the difficulties in high-tension insulators are, most of them, due to defects depending upon the history of the individual insulator, that puts a premium on the two-piece insulator immediately. You have two shells independently made, and put them together. If one shell is defective you will not, in all probability, have another defective shell along with that. But if you use the two-piece insulator, you must have its flash-over voltage so low that a single piece of porcelain will be sufficient to withstand the full strain and prevent a puncture. If you are relying on one shell when the other is injured, you must be sure to have that shell built to take care of the flash-over by itself alone. This double-piece insulator has a great advantage mechanically, in that, if due to expansion, or heavy stress, there is a little check on the inner petticoat, due to mechanical reasons, that still leaves the outer shell intact. The mechanical strains on the outer shell are far less, on account of the larger hole in which the cement is placed. We will say that this two-piece insulator, which I have in mind, flashes over at about 90,000 volts, and has a puncture stress, depending on how quickly the voltage is brought up, between 190,000 and 200,000 volts—that is, more than 2 to 1—if you do not keep the voltage on more than two or three seconds in bringing it up. This is, I believe, an exceedingly important matter. A number of these insulators have been given a high-frequency test, 250,000 and 300,000 vo'ts, considerable capacity, with long series gaps, and they have shown up very well.

R. J. McClelland: As to tower specifications, I am thoroughly in agreement that in all tower calculations the figured ultimate strength of the structure should be determined by the elastic limit of the steel; also that at least one of each type of tower should be tested to failure and the working loads for which the tower is to be used checked against the actual ultimate strength.

With regard to the term " factor of safety," I am of the opinion that the use of this term as applied to a transmission line tower, as a whole structure, is misleading and should be abandoned,

and that the term "margin of safety" should be adopted in its stead. The term "factor of safety" should be used then only with reference to the unit stresses of the individual members of the structure.

The term "margin of safety" indicates the relative excess strength of the built-up structure, and has no direct relation to the unit stresses in the members.

When writing specifications for towers one should consider the specified test loads as being practically the ultimate strength of the structure. The working loads should then be specified with an ample margin of safety, and these working loads should be put in the specifications for field use, instead of the test loads. In this way, the tendency of the construction men to consider the tower good for all loads that do not exceed test loads will be avoided.

With regard to tower footings, it would be valuable to receive data from various engineers as to the comparison of steel footings in earth with similar footings encased in concrete. In some earths and localities a standard type of concrete footing can be installed as cheaply as a safe earth footing and gives much better construction while in other situations the earth footing is amply safe and much cheaper. In the case of towers with concrete footings, I consider it well to make a substantial earth connection this is a feature that has been neglected on many of the earlier lines.

It would be valuable to possess reliable data on the action of alkaline soils on steel or concrete tower footings and on the effectiveness of concrete waterproofing methods, either integral or external, in preventing this action. When earth footings are used in acid or alkali soils, we would recommend protection of the stubs either by the application of coal tar or other suitable paint for perhaps two feet (60 cm.) below and one foot (30 cm.) above ground level, or by a concrete sleeve cast in a hinged sheet steel or other form, covering the same portion of the steel stub. Both methods leave the towers well grounded through the steel grillage of stubs and provide additional protection at the point where corrosion is likely to be most active.

Taking up the question of the arrangement of conductors, with regard to the "staggering" of conductors in vertical arrangement, it would be interesting to learn from the engineers who have used the extended middle arm construction if this has given the desired freedom from "sleet jump" troubles. Has it been proved that 2 to 3 ft. (60 to 91 cm.) horizontal offset in a span of over 1000 ft. (305 m.) gives satisfactory operating conditions at voltages of 60 kv. and over?

For protection against severe wind conditions only, the vertical arrangement of conductors is the better, whereas the horizontal arrangement of conductors is better for protection against sleet troubles.

In some recent 110-kv. construction, an interesting expedient

has been used to guard against excessive sag produced in one span due to unequal distribution of sleet over the adjacent spans. At every third or fourth suspension tower a special "semi-tension" insulator construction is used; that is, instead of one single string of insulators in suspension which allows the conductor to move in the direction of the line, as much as 14 in. (35 cm.) in the case of extreme uneven sleet load, two strings have been used, attached to the tower at an angle of 45 deg. like an inverted V. Under normal conditions a tower with this construction is practically a suspension tower, and the conductor runs straight through without a sudden change in direction, such as occurs at a tower equipped with tension insulators and a jumper; but whenever unequal sleet loading takes place, the tendency of the heavily loaded span is to rob the adjacent spans of their sag, and this is opposed by one of the "semi-tension" strings acting more as a tension insulator. I understand that sand-bag loading tests have indicated this construction to be effective and the application of this idea might prove of benefit for existing lines in the heavy sleet territories. This installation will be watched with interest.

It may be noted that I have used the term "tension insulator" in place of the usual "strain insulator." as the former designation would seem more closely descriptive of the actual working conditions of the insulator.

As to railroad and telephone crossings, during the past year we have installed a modified type of crossing protection on our lines in various parts of the country, that has met with the approval of the railroads and the signal companies. This construction consists of two parallel strings of standard suspension insulators spaced 15 in. (38 cm.) apart in the direction of the line, suspended from the ends of a Z bar rigidly secured at right angles to the axis of the crossarm, and the suspension clamps positively spaced at the conductor end by a malleable cast iron bar; the latter serves as the clamping piece in both suspension clamps, and has projecting ends which act as arcing tips. Standard towers designed for use with either suspension or tension insulators are used at each end of the crossing span, this span being somewhat reduced in length compared with the normal span. The main considerations leading to the adoption of this construction were as follows:

(1) That of increasing the safety of the crossing span by the use of an extra string of suspension insulators to support the conductor in case of mechanical failure of one string.

(2) The elimination of tension insulators, which, in our opinion, do not increase the safety of the crossing span as regards the falling of conductor, and are, moreover an extra hazard to the operation of the line.

(3) The desire to obtain satisfactory results without going into elaborate constructions, which in themselves are frequently more of a hazard than otherwise.

It is the experience of our companies that a large proportion

of troubles originate from insulator failures rather than from mechanical failure of the conductors, and in this double suspension construction we have worked on the principle of increasing the margin of safety in the insulators supporting the conductor.

With the rapid advance into higher transmission voltage the present crossing specifications providing the same construction for all voltages of 5000 or over have become inadequate to meet all the conditions involved, and in order to cover logically the wide range embraced there seems to be a distinct demand for subdividing into at least two classes, perhaps at about 15,000 volts. This would require a separate complete specification embodying simpler, but effective types of construction for the lower or distributing voltages, and another specification suitable for the higher or transmission voltages.

Concerning transmission line hardware, for all heavy service I have found it desirable to eliminate malleable cast iron hardware, and it would be well if structural or pressed steel fittings, or mild steel castings, were developed for this service, on account of the increased reliability that would be obtained thereby.

On certain recent double-circuit tower line construction our company has equipped both suspension and tension clamps of all insulator strings of one circuit with discharge horns, leaving the other circuit with discharge horns on tension clamps only. It will be interesting to compare the performance of these two circuits in service.

V. Karapetoff: I wish to take exception to the stat ment No. 5, in Mr. Buck's paper, where he says, " Draw the conductor up tight throughout the line. A too conservative allowance of slack to guard against possible mechanical stresses in the conductor will cause more trouble than it will prevent." I am afraid this statement, coming from such an authority as Mr. Buck is, will cause us more trouble than it will prevent. Several cases came to my attention not long ago where considerable trouble was caused by the conductor being drawn too tight, without reference to the stresses in the winter or during high winds. By interviewing the line superintendents, I found out that it is difficult to force the construction gangs and the foreman to conform to the tables of sags and also to use the dynamometer where the sag is determined by sighting the line. I wish very much that Mr. Buck would modify his statement so as to remove the impression that he does not believe at all in the correct calculation of sags and stresses, but simply advises us to draw up the lines as tight as possible.

P. M. Lincoln: Mr. Faccioli does not approve of switching on the high-tension sides of lines. Personally, I must say that I do not agree entirely with that position. Practically, I have never seen any bad effects from switching on the high-tension side, and theoretically I have always taken this position, namely, that although I am ready to admit that switching on the high-tension side does give rise to surges, these surges which it

gives rise to are so small, compared to the surges which come from other operations, particularly from lightning, that if the apparatus is not capable of withstanding all the surges which arise from high-tension switching it surely will not stand the surges which arise from lightning.

I would like to make a statement in regard to the point just raised by Mr. Karapetoff. I am inclined to believe that Mr. Buck is quite correct in the way he puts it. I do not believe that any great difficulties are to be anticipated from drawing lines too tight. I think the tendency is in the other direction—to allow them to become too loose. If a line is put up too tight and cold weather comes along, it may possibly strain the material of the line above the elastic limit, but what is going to happen if it does? It simply stretches a little, and when the warm weather comes along the stretch will result in a little more sag than before, but to stretch the material of the line above the elastic limit is not necessarily going to hurt the material. The material, in the course of its manufacture, has been strained above its elastic limit continuously, and if it is strained above the elastic limit after it is in service it is not by any means fatal to the line.

Farley Osgood: I think the manufacturers of our various lines of materials are doing about all that can be expected of them in the way of investigation for improvement. I do not think that the operating engineers, as a whole, are doing their share of investigating work. I think that it is up to the operating engineers to plan to spend sufficient money for proper testing schemes and devices, in order to help the manufacturers and designing engineers in the field, so that they can test in actual practise.

A point which has brought this matter vividly to my mind within the year has been our own considerable expenditure toward the investigation of the effect of high frequencies on the insulators and lines, and we found that insulators which had behaved reasonably well, as we thought, broke down very quickly under our high-frequency test.

Mr. Faccioli brought out clearly that the difficulties from voltage can be reasonably well cared for, and the difficulties from short circuits can be reasonably well cared for, particularly by means of reactance, but I do not agree with him at all that we should keep away from frequent switching. It cannot be done, in a complicated, busy territory. In our large power stations, with a heavy service, we will switch for one cause and another, twenty to sixty times a day. It cannot be stopped. It has to be done. The engineers have to meet these conditions. I entirely agree with Mr. Lincoln that if the apparatus will not meet the service requirements it must be made to.

In my opinion, the difficulties from high frequencies are not well enough understood. The reason they have not been given careful study previously is because we have been so busy eliminating the difficulties from short circuits, high pressures, etc.

Having cared for these, we can now take up the study of the effects of high frequencies. If we had done this before, many of our present difficulties would not have been known to us.

J. A. Sandford, Jr.: Mr. Brundige has suggested that engineers put into every insulator specification a description of the materials to be used. I do not believe that is a possibility. I had occasion to look up not long ago the chemical analysis as laid down for what we call ball clay, or kaolin, from Kentucky, North Carolina, Georgia, one or two places in England, and one in France. You could lay these in a row here on this table and label them, and then take the labels off, and change them around, and you would never know which applied to which, they are so nearly the same. The great difference between the various clays used seems to be in their plasticity, but no one can tell what plasticity is or what causes it. Therefore, I think Mr. Brundige's suggestion would prove impracticable, particularly at the present time, with our limited knowledge of such things.

Second, on the question of fatigue of porcelain. I think that if a piece of porcelain is absolutely vitrified there is absolutely no fatigue. To my mind, what has been called fatigue of porcelain is simply the gradual giving way of porcelain that, in the first place, was not perfect, either through flaws, or from the vitrification standpoint.

To refer to a different matter, I think that a large percentage of the insulator failures on transmission lines would have been eliminated if, every time the patrolman went out to change an insulator—this has reference particularly to suspension type insulator lines—he had taken down the complete string of insulators and substituted a complete string of new insulators which he was sure were good. If you go out and look at a string of insulators on which you know there is trouble, there may be two or three disks that you can see are no good, and there may be two or three that look as if they are all right, and they may or may not be so.

There is one point Mr. Sothman brought up today, which was referred to here last winter, which I would mention again now, and that is the desirability of having at some place or other a laboratory where just and accurate comparative work on insulators and other similar devices can be done. The insulator manufacturers have done, as some one has said, about all they can do. It seems to me if the plan of having such a central testing laboratory could be carried out, either with or without the sanction of the Institute, it would be a great thing.

E. R. Albrecht: I notice in Mr. Sothman's paper, "Problems of High-Tension Transmission Lines," the following statement, relative to the crossing of high-tension lines—"There is at present no generally recognized type of crossing protection."

Did not the High-Tension Committee of 1911, together with the committee appointed by the National Electric Light Association, the American Electric Railway Association, and

the Association of Railway Telegraph Superintendents, prepare Specifications for Overhead Crossings of Electric Light and Power Lines, which were accepted by the various associations?

Have these specifications still the approval of the Institute? Do they not cover the recognized type of crossing protection? If they do, why did not Mr. Sothman mention them? If not, what parts should be superseded, and by what?

The installation of proper crossing protection constitutes a part of my duties, and I am very much interested to know just how the Institute as a whole regards the specifications mentioned, and also, if the present High-Tension Committee recommend their use, and if not, whether they have any plans for revising them.

William L. Puffer: I am very much interested in what has been said concerning the life, deterioration of and failure of the several types of insulators in common use, because of an investigation of mine into the cause of undue leakage over the busbar cell-work and insulations of a moderately high tension station.

In this station it was known that there was some kind of ground or similar trouble, because at times tiny sparks had been noted at the heads of bolts and washers used in assembling the insulating slabs, and several disagreeable shocks had been received by attendants. As soon as possible a section was cut out of service and the parts dismantled, and to my surprise there was found a large collection of wet green paste on the copper bolts and studs. Chemical examination proved the presence of nitric acid, water, nitrate of copper and several sub-nitrates. The surface of the porcelains and all pores and cracks were wet with nitric acid of sufficient strength to destroy organic washers that had been used to distribute the pressure between the porcelain and the clamping nuts and bolts.

Further examination proved the presence of nitric acid in the cracks of both wet and dry process porcelain bushing, on the surface of the insulating coverings of the busbar cables and on the porcelain bushings used to support the cables where they passed through walls and barrier.

I was able to prove that all of the trouble originated in the small air spaces where the potential gradient was high enough to produce light and minute sparks of the type called " static ". First there was produced ozone, then nitric acid and then action on the copper with the formation of nitrates. Similar action was found about some iron washers and bolts used in the construction of switches and the switchboard.

These results were not a matter of conjecture but of actual chemical proof obtained while the parts were alive and carrying current, and it certainly suggests that if a 6600-13,200 volt system can be subject to as great action as I found, there is ample room for thought as to what must be the conditions around the insulating parts of the highest tension lines now in use.

Whenever and wherever an insulating support shows a glow

with l'ttle sparks in it there is likely to be the formation of ozone, and if a little moisture is present there will next be nitric acid. The wind may blow it all away, or a porous porcelain may slowly absorb it, with gradually lessening resistance, leading finally to a puncture and a short-circuit.

Ernest V. Pannell: Mr. Sothman's suggestion as to the establishment of constants to cover the commercial properties of aluminum and copper is one well worth acting upon, and it would afford the manufacturer some idea of what he would have to work on and would give the engineer figures upon which to base his calculations. At present there is no recognized standard for these properties, and specifications are different all along. In particular reference to aluminum, the specification of elastic limit should have some reference to the size of the wire, as I have found on test that the elastic limit varies from 10,000 up to 20,000 with decrease in the gage. The new German rules, it is interesting to note, do not specify elastic limit for conductor material, but only elasticity, and give a maximum figure of 10,000 lb. per square inch for the stress in aluminum. This latter practise is to be deprecated, as it does not offer the same encouragement to the manufacturer to produce material of extra high grade as when the working tension is specified at so much per cent on the elastic limit.

Of methods and charts for determining tension and sag we have had rather a plethora, and if the Institute were to standardize one set of curves for both copper and aluminum, the result would be worth the trouble expended. The *Verein Deutscher Elektrotechniker* went into this subject very thoroughly last year and their recently published hand-book of standards for overhead lines is a model of conciseness.

Regarding steel reinforcement for aluminum cables, the British manufacturers do not view this practise with disfavor so much as being an unnecessary innovation. We can point to spans in Europe of 700 ft. (213 m.) and up to 2000 ft. (610 m.) being run by aluminum without steel centers, so there does not appear to be any crying need for reinforcement where the highest possible grade of aluminum is used. A composite cable made up of two materials, one of which has three times the specific extension of the other, seems to add just a little unnecessary complexity.

Julian C. Smith: I think operating men who have had experience in operating transmission lines of 50,000 volts and upwards, with pin type insulators, realize there has been a decided deterioration in the pin type insulators. The fact that it is easier to find the deterioration in the suspension type insulator, easier to replace the defective parts, would by no means indicate that the suspension type, *per se*, is any worse than the pin type. This is the more evident when you consider that practically all suspension type insulators are operating with one end grounded, whereas a relatively small number of pin type insulators subjected to the same voltage, are operating under these conditions.

There is one point in Mr. Buck's paper to which I take ex-

ception, and that is the number of units which would be put on very important transmission lines. It seems to me that the number of units should be fixed by the climatic conditions or local conditions rather than the operating voltage.

E. A. Lof: Mr. Sothman suggested that the clearance between the transmission wires and the ground should be in a certain relation to the transmission voltage. So far as I can see, this has nothing to do with the voltage, whether it is 50,000 or 150,000 volts. We must string the wires high enough to protect human life and to allow certain vehicles to pass underneath.

I would like to get Mr. Sothman's views on the necessity of grounding steel towers when provided with concrete foundations, and his views on the mounting of grounded wires on wooden poles. If the ground wire is not grounded at every pole, should it be supported on an insulator there, and if so, for what voltage should it be insulated?

C. O. Mailloux: One of our distinguished members, Cavv. Ing. Guido Semenza, of Milan, Local Honorary Secretary of the A. I. E. E. for Italy, has recently published a comprehensive set of charts containing in graphical form all the information needed for running overhead lines; *i.e.*, giving the sags and stresses that occur in overhead conductors of different sizes, in spans of different lengths, at all temperatures, and under all conditions of extra loading due to ice and wind. By means of these charts all determinations of sags and stresses for any set of conditions can be made in most simple manner by the man in charge of the work of constructing the line. It is probable that an English edition of this work will be brought out before long.

E. M. Hewlett: Mr. Buck has explained that if an insulator is designed with a petticoat so short that the flash-over point is much lower than the puncture point, normally, under both dry and wet conditions, the insulator will be less severely strained and will not be subject to as rapid deterioration as has been shown by some of the insulators used now. A number of the recent insulators have too great a diameter of petticoat, so the flash-over is too close to the puncture voltage.

Then, again, if you insulate your line for lightning conditions, as suggested by one of the last speakers, it will also be necessary to protect or insulate the transformers, lightning arresters, switches and everything else for the same conditions. This is an most important consideration.

Also, in the matter of mechanical strength, the distortion in design of the insulator to give great strength often works against the electrical characteristics. You thus handicap yourself when you ask for strength greater than is required.

In reference to the fatigue of porcelain, I have not seen the proof that well-vitrified porcelain undergoes fatigue, unless overstrained. From anything we have seen so far, I believe that what is known as fatiguing is largely the result of flaw of some description or of incomplete vitrification. That is, when not properly vitrified, the insulators will eventually absorb moisture. The glaze will

protect the insulator for a time, but gradually deteriorates and then absorption through the porcelain begins and the unbaked porcelain gradually absorbs moisture and breaks down.

H. W. Buck: I am glad that Dr. Karapetoff has raised the question covered by Paragraph 5 in the conclusions at the end of my paper, for it offers an opportuntity to accentuate the point which I desired to cover in this paragraph. Most transmission lines are too slack, and during the past year reports have come in from all parts of the country giving instances of short circuits resulting from conductors swinging together under wind stress, even where liberal clearances were allowed between conductors.

It has become customary to assume a heavy loading of sleet and the simultaneous action of wind velocities up to 100 miles (161 km.) per hour, allowing slack for these conditions, and then in addition to throw in a little for good luck. On top of all this slack, after the line has been in service for a few months the natural stretch which takes place in all conductor materials before a condition of permanent set has been established, still further increases the sag of the spans. The result of this is that many transmission lines are a series of festoons between tower supports, with all the lack of inherent stability which such a condition gives rise to.

I cannot see any reason for modifying this statement in regard to drawing the wires up tight, unless by supplementing it with a statement that the towers must be made strong enough to withstand the strain. The first line of the paragraph in question should of course be read in connection with the following three lines, which qualify it, I believe, sufficiently.

K. C. Randall: Mr. Rushmore has pointed out that insulators have not been developed along the lines of exact science

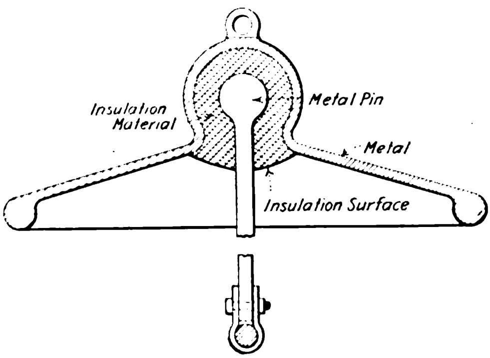


FIG. 1

like other pieces of electrical apparatus. This comment seems to be well founded so far as the average commercial insulator is concerned.

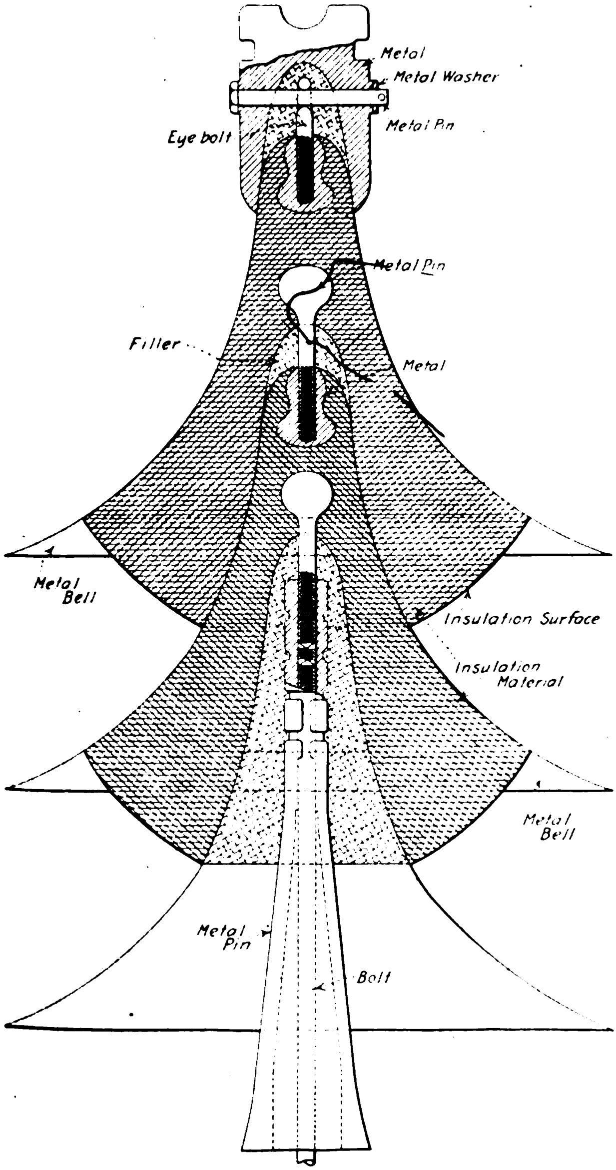

Metal
Metal Washer
Metal Pin
Eye bolt
Metal Pin
Filler
Metal
Metal Bell
Insulation Surface
Insulation Material
Metal Bell
Metal Pin
Bolt

FIG. 2

During the past five years considerable investigation on the proper design of insulation has been carried on, in the course of which the influence of shape as well as dimensions has been better understood. As a striking illustration of this, the Institute is considering the standardization of a spherical or ball gap, because of its dependability, as a successor to the previous needle gap, so notoriously variable.

In March, 1913, Mr. C. Fortescue presented a paper before the Institute bringing out a considerable amount of the data obtained in the investigations I refer to, and, based on such data, two designs of insulators have been proposed which are based on truly scientific lines, and what is more striking, they are made up largely of metal. Fig. 1 illustrates a type quite like the ordinary suspension insulator, the petticoats of which, however, are metal and will certainly not crack off, as is commonly experienced with the porcelain type. As a form of pin insulator, Fig. 2 illustrates a design also based on scientific principles, whose dimensions for any service can be definitely and closely calculated, and whose breakdown tests can be predetermined.

It is suggested that further development along these lines will probably be very fruitful of progress, which today's discussion has pointed out as much needed.

STANDARDIZATION RULES

OF THE

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

HISTORY OF THE STANDARDIZATION RULES

The first step taken by the Institute toward the standardization of electrical apparatus and methods was a topical discussion on "The Standardization of Generators, Motors and Transformers," which took place simultaneously in New York and Chicago on the evening of January 26, 1898. The discussion appears in the Institute TRANSACTIONS, Vol. XV, pages 3 to 32. The opinions expressed were generally favorable to the scheme of standardization of electrical apparatus, although some members feared that difficulties might arise. As a result of this discussion, a Committee on Standardization was appointed by the Council of the Institute, consisting of the following members:

FRANCIS B CROCKER, *Chairman.*

CARY T. HUTCHINSON	CHARLES P. STEINMETZ
ARTHUR E. KENNELLY	LEWIS B. STILLWELL
JOHN W. LIEB, JR.	ELIHU THOMSON

After a careful consideration of the matter and consultation with the members of the Institute and interested parties generally, a "Report of the Committee on Standardization," was presented and accepted by the Institute, June 26, 1899. Those original rules appeared in the Institute TRANSACTIONS, Vol. XVI, pages 255 and 268.

As a result of changes and developments in the electric art, it was subsequently found necessary to revise the original report, this work being carried out by the following Committe on Standardization:

FRANCIS B. CROCKER, *Chairman.*

ARTHUR E. KENNELLY	CHARLES P. STEINMETZ
JOHN W. LIEB, JR.	LEWIS B. STILLWELL
C. O. MAILLOUX	ELIHU THOMSON

This revised report was adopted at the 19th Annual Convention at Great Barrington, Mass., on June 20, 1902, and appears in the Institute TRANSACTIONS, Vol. XIX, pages 1075 to 1092.

In consequence of still further change and development in electrical apparatus and methods, it was decided in September, 1905, that a second revision was needed, and the following Committee was appointed to do this work.

FRANCIS B. CROCKER, *Chairman.*
ARTHUR E. KENNELLY, *Secretary.*

HENRY S. CARHART	CHARLES F. SCOTT
JOHN W. LIEB, JR.	CHARLES P. STEINMETZ
C. O. MAILLOUX	HENRY G. STOTT
ROBERT B. OWENS	S. W. STRATTON

This Committee held monthly meetings and carried on extensive correspondence with manufacturers, consulting and operating engineers and other interested parties, and as a result, presented its report at the 23d Annual Convention, held at Milwaukee, May 28–30, 1906. After considerable discussion the report was accepted and referred back to the Committee for amendment and rearrangement in form. It was then to be submitted to the Board of Directors for final adoption. In September, 1906, the following Standardization Committee was appointed:

FRANCIS B. CROCKER, *Chairman.*
ARTHUR E. KENNELLY, *Secretary.*

A. W. BERRESFORD	CHARLES F. SCOTT
DUGALD C. JACKSON	CHARLES P. STEINMETZ
C. O. MAILLOUX	HENRY G. STOTT
ROBERT B. OWENS	S. W. STRATTON

ELIHU THOMSON

This Committee held monthly meetings, also sub-committee meetings, and carefully referred the rules as a whole, and each part of them, to the members of the Institute. The rules were also entirely rearranged as to form, and put in shape to facilitate ready reference to them and enable future revisions to be made without breaking up the logical arrangement. Thus amended the rules were submitted to the Board of Directors and approved by it on June 21, 1907. The Board also directed that the rules should be presented, as accepted by the Board, at the Annual Convention held at Niagara Falls, June 24 to 27, 1907, which action was taken by President Sheldon on June 26, 1907. By the Constitution which went into effect on June 10, 1907, this Committee has been made a standing Committee with the title " Standards Committee," consisting of nine members.

On August 12, 1910, the Board of Directors increased the size of the committee from nine to twelve members; on October 14 from twelve to fourteen, and on March 10, 1911, from fourteen to sixteen. The committee thus constituted is given below.

COMFORT A. ADAMS, *Chairman.*
ARTHUR E. KENNELLY, *Secretary.*

H. W. BUCK	W. S. MOODY
GANO DUNN	R. A. PHILIP
H. W. FISHER	W. H. POWELL
H. B. GEAR	CHARLES ROBBINS
J. P. JACKSON	E. B. ROSA
W. L. MERRILL	CHARLES P. STEINMETZ
RALPH D. MERSHON	CALVERT TOWNLEY

This committee and several sub-committees held numerous meetings at which the general revision of the Standardization Rules of the Institute was considered. The complete Standardization Rules, as revised by this committee, were presented to and approved by the Board of Directors on June 27, 1911, at the Annual Convention held at Chicago, Ill.

The committee reappointed in August 1913 was enlarged by the Board of Directors in order to permit of sub-committees being formed on sectional parts of the work. The committee thus constituted is given as follows:

A. E. Kennelly, *Chairman.*
Comfort A. Adams, *Secretary.*

SUB-COMMITTEE No. 1. ON RATING.

H. M. Hobart, *Chairman.*

James Burke
W. C. L. Eglin
B. G. Lamme
W. A. Layman
W. L. Merrill
W. S. Moody
W. H. Powell
Charles Robbins
C. F. Scott
James M. Smith
Charles P. Steinmetz
J. Franklin Stevens
Philip Torchio

SUB-COMMITTEE No. 2. ON TELEGRAPH AND TELEPHONE STANDARDS.

F. B. Jewett, *Chairman.*

H. W. Fisher
F. F. Fowle
R. H. Marriott
J. H. Morecroft
J. M. Smith

SUB-COMMITTEE No. 3. ON RAILROAD STANDARDS.

W. A. Del Mar, *Chairman.*

F. W. Carter*
Hugh Hazelton*
E. R. Hill*
H. M. Hobart
William McClellan
Harold Pender
Martin Schreiber*
N. W. Storer*

SUB-COMMITTEE No. 4. ON NOMENCLATURE AND SYMBOLS.

Comfort A. Adams, *Chairman.*

Louis Bell
Dugald C. Jackson
M. G. Lloyd
H. Pender
E. B. Rosa
A. S. McAllister
R. H. Marriott

SUB-COMMITTEE No. 5. ON WIRES AND CABLES.

H. W. Fisher, *Chairman.*

Wallace Clark
W. A. Del Mar
W. C. L. Eglin
E. B. Rosa
C. E. Skinner
S. W. Stratton

SUB-COMMITTEE NO. 6. ON RATING AND TESTING OF CONTROL APPARATUS.

L. T. Robinson, *Chairman.*

Morton Arendt
R. A. Carle
C. H. Sharp
P. H. Thomas
Philip Torchio

Sub-committee No. 1 had representation from the National Electric Light Association (Messrs. L. L. Elden, G. L. Knight, J. E. Kearns, and E. P. Dillon), from the Association of Edison Illuminating Companies(Mr. P. Torchio) and from the Electric Power Club (Messrs. James Burke and J. M. Smith).

Sub-committee No. 3 (through Messrs. Schreiber and Del Mar, respectively (worked in collaboration with the Committees of the American Electric Railway (Engineering) Association, and the Association of Railway Electrical Engineers.

*Sub-committee No. 3 was a joint subcommittee of the Standards Committee and of the Railway Committee. The members opposite whose names occurs an asterisk, represented the latter committee.

The following members, although not appointed on the Standards Committee, have materially contributed to its work and have attended its meetings:

Carl J. Fechheimer, E. D. Priest, R. B. Williamson, K. A. Pauly, L. F. Blume, C. Renshaw, G. H. Hill, C. J. Hixson.

The following resolution regarding the Standardization Rules was adopted by the Board of directors July 10, 1914.

"*Resolved*, that the Rules reported by the Standards Committee be and hereby are adopted, subject to editorial revision by the Committee for the purpose of correcting errors and clarifying the real intent of the rules, the same to take effect December 1, 1914."

NOTE.

The Standards Committee takes this occasion to draw the attention of the membership to the value which attaches to suggestions based upon experience gained in the course of the application of the Rules to general practise.

Any suggestions looking toward improvement in the Rules should be communicated to the Secretary of the Institute for the guidance of the Standards Committee in the preparation of future editions.

TABLE OF CONTENTS

DEFINITIONS

NOTE. The following definitions are intended to be practically descriptive, and not scientifically rigid.

CURRENT, E.M.F. and POWER.

(The definitions of currents given below apply also, in most cases, to electromotive force, potential difference, magnetic flux, etc.

1 **A Direct Current** is a unidirectional current. As ordinarily used, the term designates a practically non-pulsating current.

2 **A Pulsating Current** is a current which pulsates regularly in magnitude. As ordinarily employed, the term refers to unidirectional current.

3 **A Continuous Current** is a practically non-pulsating direct current.

4 **An Alternating Current** is a current which alternates regularly in direction. Unless distinctly otherwise specified, the term " alternating current " refers to a periodic current with successive half waves of the same shape and area.

5 **An Oscillating Current** is a periodic current whose frequency is determined by the constants of the circuit or circuits.

6 **Cycle.** One complete set of positive and negative values of an alternating current.

7 **Electrical Degree.** The 360th part of a cycle.

8 **Period.** The time required for the current to pass through one cycle.

9 **Frequency.** The number of cycles or periods per second. The product of 2π by the frequency is called the *angular velocity* of the current.

10 **Root-Mean-Square or Effective Value.** The square root of the mean of the squares of the instantaneous values for one complete cycle. It is usually abbreviated r.m.s. Unless otherwise specified, the numerical value of an alternating current refers to its r.m.s. value. The r.m.s. value of a sinusoidal wave is equal to its maximum value divided by $\sqrt{2}$. The word "virtual" is sometimes used in place of r.m.s., particularly in Great Britain.

11 **Wave-Form or Wave-Shape.** The shape of the curve obtained when the instantaneous values of an alternating current are plotted against time in rectangular co-ordinates. The distance along the time axis corresponding to one complete cycle of values is taken as 2π radians, or 360 degrees. Two alternating quantities are said to have the same wave-form when their ordinates of corresponding phase (see **§ 13**) bear a constant ratio to each other. The wave-shape, as thus understood, is therefore independent of the frequency of the current and of the scale to which the curve is represented.

12 **Simple Alternating or Sinusoidal Current.** One whose wave-shape is sinusoidal.

Alternating-current calculations are commonly based upon the assumption of sinusoidal currents and voltages.

13 **Phase.** The distance, usually in angular measure, of the base of any ordinate of an alternating wave from any chosen point on the time axis, is called the phase of this ordinate with respect to this point. In the case of a sinusoidal alternating quantity, the phase at any instant may be represented by the corresponding position of a line or *vector* revolving about a point with such an angular velocity ($\omega = 2\pi f$) that its projection at each instant upon a convenient reference line is proportional to the value of the quantity at that instant.

14 **Non-Sinusoidal Quantities** are quantities that cannot be represented by vectors of constant length in a plane, and the following definitions of phase, active component, reactive component, etc., are not in general applicable. Certain "equivalent" values, as defined below, may, however, be used in many instances, for the purpose of approximate representation and calculation.

15 **Crest-Factor or Peak-Factor** is the ratio of the crest or maximum value to the r.m.s. value. The crest factor of a sine-wave is $\sqrt{2}$.

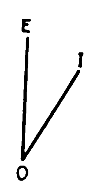
16 **Form Factor** is the ratio of the r.m.s. to the algebraic mean ordinate taken over a half-cycle beginning with the zero value. If the wave passes through zero more than twice during a single cycle, that zero shall be taken which gives the largest algebraic mean for the succeeding half-cycle. The form factor of a sine-wave is 1.11.

17 **Distortion Factor** of a wave is the ratio of the r.m.s. value of the first derivative of the wave with respect to time, to the r.m.s. value of the first derivative of the equivalent sine wave.

18 **Equivalent Sine Wave.** A sine wave which has the same frequency and same r.m.s. value as the actual wave.

*19 **Phase Difference: Lead and Lag.** When corresponding cyclic values of two sinusoidal alternating quantities of the same frequency occur at different instants, the two quantities are said to differ in phase by the angle between their nearest corresponding values, *e.g.*, the phase angle between their nearest ascending zeros or positive maxima. That quantity whose maximum value occurs first in time is said to lead the other, and the latter is said to lag behind the former.

*20 **Counter-Clockwise Convention.** It is recommended that in any vector diagram, the leading vector be drawn counter-clockwise with respect to the lagging vector, † as in the accompanying diagram, where OI represents the vector of a current in a simple alternating-current circuit lagging behind the vector OE of impressed e.m.f.



*21 **The Active or In-Phase Component** of the current in a circuit is that component which is in phase with the voltage across the circuit; similarly the active component of the voltage across a circuit is that component which is in phase with the current. The use of the term *energy component* for this quantity is disapproved.

*Note: Definitions 19, 20, 21, 22, 23, 24, 25 refer strictly only to cases where the voltage and current are both sinusoidal (see §12).

†See Publication 12 of the International Electrotechnical Commission (Report of Turin Meeting, Sept. 1911, p. 78).

*22 **The Reactive or Quadrature Component** of the current in a circuit is that component which is in quadrature with the voltage across the circuit; similarly the reactive component of the voltage across the circuit is that component which is in quadrature with the current. The use of the term *wattless component* for this quantity is disapproved.

*23 **Reactive Factor** is the sine of the angular phase difference between voltage and current, or the ratio of the reactive current or voltage to the total current or voltage.

*24 **Reactive Volt-Amperes.** The product of the reactive component of the voltage by the total current, or of the reactive component of the current by the total voltage.

*25 **Non-Inductive Load and Inductive Load.** A *non-inductive* load is a load in which the current is in phase with the voltage across the load. An *inductive* load is a load in which the current lags behind the voltage across the load. A *condensive* or *anti-inductive* load is one in which the current leads the voltage across the load.

26 **Power in an Alternating-Current Circuit** is the average value of the products of the coincident instantaneous values of the current and voltage for a complete cycle, as determined by a wattmeter.

27 **Volt-Amperes or Apparent Power.** The product of the r.m.s. value of the voltage across a circuit by the r.m.s. value of the current in the circuit. This is ordinarily expressed in kv-a.

28 **Power Factor** is the ratio of the power (cyclic average as defined in **§26**) to the volt-amperes. In the case of sinusoidal current and voltage, the power factor is equal to the cosine of their difference in phase.

29 **Equivalent Phase Difference.** When the current and e.m.f. in a given circuit are non-sinusoidal, it is customary, for purposes of calculation, to take as the "equivalent" phase difference the angle whose cosine is the power factor (see **§28**) of the circuit. There are cases, however, where this equivalent phase difference is misleading, since the presence of harmonics in the voltage wave, current wave, or in both, may reduce the power factor without producing a corresponding displacement of the two wave forms with respect to each other; *e.g.*, the case of an a-c. arc. In such cases the components of the equivalent sine waves, the equivalent reactive factor and the equivalent reactive volt-amperes may have no physical significance.

30 **Single-Phase.** A term characterizing a circuit energized by a single alternating e.m.f. Such a circuit is usually supplied through two wires. The currents in these two wires, counted positively outwards from the source, differ in phase by 180 degrees or a half-cycle.

31 **Three-Phase.** A term characterizing the combination of three circuits energized by alternating e.m.f.'s. which differ in phase by one-third of a cycle; *i.e.*, 120 degrees.

***Note: Definitions 19, 20, 21, 22, 23, 24, 25 refer strictly only to cases where the voltage and current are both sinusoidal (see §12).**

32 **Quarter-Phase, also called Two-Phase.** A term characterizing the combination of two circuits energized by alternating e.m.f's. which differ in phase by a quarter of a cycle; *i.e.*, 90 degrees.

33 **Six-Phase.** A term characterizing the combination of six circuits energized by alternating e.m.f's. which differ in phase by one sixth of a cycle; *i.e.*, 60 degrees.

34 **Polyphase** is the general term applied to any system of more than a single phase. This term is ordinarily applied to symmetrical systems.

Per Cent Drop.

35 In electrical machinery, the ratio of the internal resistance drop to the terminal voltage is called the "*per cent resistance drop*."

36 Similarly the ratio of the internal reactance drop to the terminal voltage is called the "*per cent reactance drop*."

37 Similarly the ratio of the internal impedance drop to the terminal voltage is called the "*per cent impedance drop*."

Unless otherwise specified, these per cent drops shall be referred to rated load and rated power factor.

38 In the case of transformers, the per cent drop will be the primary drop (reduced to secondary turns) plus the secondary drop, in per cent of secondary terminal voltage.

39 In the case of induction motors, it is advantageous to express the drops in per cent of the internally induced e.m.f.

40 **The Load Factor** of a machine, plant or system is the ratio of the average power to the maximum power during a certain period of time. The average power is taken over a certain period of time, such as a day, a month, or a year, and the maximum is taken over a short interval of the maximum load within that period.

In each case, the interval of maximum load and the period over which the average is taken should be definitely specified, such as a "half-hour monthly" load-factor. The proper interval and period are usually dependent upon local conditions and upon the purpose for which the load factor is to be used.

41 **Plant Factor** is the ratio of the average load to the rated capacity of the power plant.

42 **The Demand** of an installation or system is the load which it puts on the source of supply, as measured at the receiving terminals. The demand may be as specified, contracted for, or used. It may be expressed either in kilowatts, kilovolt-amperes, amperes or other suitable units.

43 **Maximum Demand** of an installation or system is its greatest demand, as measured not instantaneously but over a suitable and specified interval, such as a "five-minute maximum demand."

44 **Demand Factor** is the ratio of the maximum demand of any system or part of a system to the total connected load of the system, or of the part of system, under consideration.

45 **Diversity Factor** is the ratio of the sum of the maximum power demands of the subdivisions of any system or parts of a system

to the maximum demand of the whole system or of the part of the system under consideration, measured at the point of supply.

46 **Connected Load.** The combined continuous rating of all the receiving apparatus on consumers' premises connected to the system or part of the system under consideration.

47 **The Saturation Factor** of a machine is the ratio of a small percentage increase in field excitation to the corresponding percentage increase in voltage thereby produced. Unless otherwise specified, the saturation factor of a machine refers to the excitation existing at normal rated speed and voltage. It is determined from measurements of saturation made on open circuit at rated speed.

48 **The Percentage of Saturation** of a machine at any excitation may be found from its saturation curve of generated voltage as ordinates, against excitation as abscissas, by drawing a tangent to the curve at the ordinate corresponding to the assigned excitation, and extending the tangent to intercept the axis of ordinates drawn through the origin. The ratio of the intercept on this axis to the ordinate at the assigned excitation, when expressed in percentage, is the percentage of saturation and is independent of the scales selected for excitation and voltage. This ratio, as a fraction, is equal to the reciprocal of the saturation-factor at the same excitation, deducted from unity, or if f be the saturation factor and p the percentage of saturation,

$$p = 100\left(1 - \frac{1}{f}\right)$$

49 **Magnetic Degree.** The 360th part of the angle subtended, at the axis of a machine, by a pair of its field poles. One mechanical degree is thus equal to as many magnetic degrees as there are pairs of poles in the machine.

50 **The Variation in Prime Movers** which do not give an absolutely uniform rate of rotation or speed, as in reciprocating steam engines, is the maximum angular displacement in position of the revolving member expressed in degrees, from the position it would occupy with uniform rotation, and with one revolution taken as 360 degrees.

51 **The Variation in Alternators** or alternating-current circuits in general, is the maximum angular displacement, expressed in electrical degrees, (one cycle = 360 deg.) of corresponding ordinates of the voltage wave and of a wave of absolutely constant frequency equal to the average frequency of the alternator or circuit in question, and may be due to the variation of the prime mover.

52 **Relations of Variations in Prime Mover and Alternator.** If p is the number of pairs of poles, the variation of an alternator is p times the variation of its prime mover, if direct-connected, and $p\,n$ times the variation of the prime mover if rigidly connected thereto in such a manner that the angular speed of the alternator is n times that of the prime mover.

53 **The Pulsation in Prime Movers,** or in the alternator connected thereto, is the ratio of the difference between the maximum and minimum velocities in an engine-cycle to the average velocity.

54 **Capacity.** The two different senses in which this word is used sometimes lead to ambiguity. It is therefore recommended that whenever such ambiguity is likely to arise, the descriptive term ***power capacity*** or ***current capacity*** be used, when referring to the power or current which a device can safely carry, and that the term "***Capacitance***" be used when referring to the electrostatic capacity of a device.

55 A **Resistor** is a device, commonly known as a resistance, used for the operation, protection, or control of a circuit or circuits.

56 A **Reactor** is a coil, winding or conductor commonly known as a reactance coil or choke coil, possessing inductance, the reactance of which is used for the operation, protection or control of a circuit or circuits.

57 **The Efficiency** of an electrical machine or apparatus is the ratio of its useful output to its total input.

58 **SYMBOLS AND ABBREVIATIONS.**

Name of Quantity.	Symbol for the Quantity.	Unit.	Abbreviation for the Unit.
Electromotive force, abbreviated e.m.f.	E, e	volt	....
Potential difference, abbreviated p.d.	V, v or E, e	"	....
Voltage	E, e or V, v	"	....
Current	I, i	ampere	....
Quantity of electricity	Q, q	coulomb or ampere-hour	....
Power	P, p	watt	....
Electrostatic flux	Ψ	....	....
Electrostatic flux density	D	....	....
Electrostatic field intensity	F		
Magnetic flux	Φ, φ	maxwell*	....
Magnetic flux density	B, $\mathcal{B}$	gauss*	....
Magnetic field intensity	H, $\mathcal{H}$	gilbert per centimeter or gauss	gilbert per cm. ....
Magnetomotive force, abbreviated m.m.f.	$\mathfrak{F}$	gilbert*	....
Intensity of magnetization	J	....	....
Susceptibility	$\kappa = J/H$	....	....
Permeability	$\mu = B/H$	....	....

* An additional unit for m. m. f. is the "ampere-turn", for flux the "line", for magnetic flux-density "maxwells per sq. in."

Resistance	R, r	ohm	....
Reactance	X, x	"	....
Impedance	Z, z	"	....
Conductance	g	mho	....
Susceptance	b	"	....
Admittance	Y, y	"	....
Resistivity	ρ	* ohm-centimeter	ohm-cm.
Conductivity	γ	* mho per centimeter	mho per cm.
Dielectric constant	ϵ or k	....	....
Reluctance	$\mathfrak{R}$	....	....
Capacitance (Electrostatic capacity)	C	farad	....
Inductance (or coefficient of self induction)	L	henry	....
Mutual Inductance (or coefficient of mutual induction)	M	henry	....
Phase displacement	θ, φ	degree or radian	deg.
Frequency	f	cycle per second	~
Angular velocity	ω	radians per second	....
Velocity of rotation	n	revolutions per second	rev. per sec.
Number of conductors or turns	N	convolutions or turns of wire	
Temperature	T, t, θ	degree centigrade	deg. cent.
Energy in general	U or W	joule or watt-hour	....
Mechanical work	W or A	joule or watt-hour	....
Efficiency	η	per cent	....
Length	l	centimeter	cm.
Mass	m	gram	g.
Time	t	second	sec.
Acceleration due to gravity	g	centimeters per second per second	cm. per sec. per sec.
Standard acceleration due to gravity (at about 45 deg. latitude and sea level) equals 980.665†	g_o	centimeters per second per second	cm. per sec. per sec.

**Note.* The numerical values of these quantities are *ohms resistance* and *mhos conductance* between two opposite faces of a cm. cube of the material in question, but the correct names are as given, not ohms and mhos per cm. cube as commonly stated.

†This has been the accepted standard value for many years and was formerly considered to correspond accurately to 45° Latitude and sea level. Later researches, however, have shown that the most reliable value for 45° and sea-level is slightly different; but this does not affect the standard value given above.

59 E_m, I_m and P_m should be used for maximum cyclic values, e, i and p for instantaneous values, E and I for r.m.s. values (see **§10**) and P for the average value or active power. These distinctions are not necessary in dealing with continuous-current circuits. In print, vector quantities should be represented by bold-face capitals.

CLASSIFICATION OF MACHINERY.

60 The machinery under consideration in these rules may be classified in various ways, these various classifications overlapping or interlocking in considerable degree. Briefly, they are Direct-Current or Alternating-Current, Rotating or Stationary. Under Rotating Apparatus there are two principal classifications: *First*, according to the function of the machines; Motors, Generators, Boosters, Motor-Generators, Dynamotors, Double-Current Generators, Converters and Phase Modifiers; Second, according to the type of construction or principle of operation; Commutating, Synchronous, Induction, Unipolar, Rectifying. Obviously some of these groups could be rationally included in either classification, *e.g.*, Motor-Generators and Rectifying Machines.

In the following, the self-evident definitions are for the most part omitted.

ROTATING MACHINES.

FUNCTIONAL CLASSIFICATION OF ROTATING MACHINES.

61 **A Generator** is a machine which transforms mechanical power into electrical power.

62 **A Motor** transforms electrical power into mechanical power.

63 **A Booster** is a generator inserted in series in a circuit to change its voltage. It may be driven by an electric motor (in which case it is termed a motor-booster) or otherwise.

64 **A Motor-Generator** is a transforming device consisting of a motor mechanically coupled to one or more generators.

65 **A Dynamotor** is a transforming device combining both motor and generator action in one magnetic field, either with two armatures, or with one armature having two separate windings and independent commutators.

66 **A Direct-Current Compensator** or **Balancer** comprises two or more similar direct-current machines (usually with shunt or compound excitation) directly coupled to each other and connected in series across the outer conductors of a multiple-wire system of distribution, for the purpose of maintaining the potentials of the intermediate wires of the system, which are connected to the junction points between the machines.

67 **A Double-Current Generator** supplies both direct and alternating currents from the same armature-winding.

68 **A Converter** is a machine employing mechanical rotation in changing electrical energy from one form into another. A converter may belong to either of several types, as follows:

69 A **Direct-Current Converter** converts from a direct current to a direct current, usually with a change of voltage. Such a machine may be either a motor-generator or a dynamotor.

70 A **Synchronous Converter** (also called a Rotary Converter) converts from an alternating to a direct current, or vice-versa. It is a synchronous machine with a single closed-coil armature.

71 A **Cascade Converter,** also called a **Motor Converter,** is a combination of an induction motor with a synchronous converter, the secondary circuit of the former feeding directly into the armature of the latter; *i.e.*, it is a synchronous converter concatenated with an induction motor.

72 A **Frequency Converter** converts the power of an alternating-current system from one frequency to another, with or without a change in the number of phases, or in the voltage.

73 A **Rotary Phase-Converter** converts from an alternating-current system of one or more phases to an alternating-current system of a different number of phases, but of the same frequency.

74 **A Phase-Modifier,** also called *a Phase-Advancer*, is a machine which supplies reactive volt-amperes to the machine; *e.g.* induction motor, or to the system to which it is connected. Phase modifiers may be either synchronous or asynchronous.

75 A **Synchronous Phase-Modifier,** sometimes called a Synchronous Condenser, is a synchronous motor, running either idle or with load, the field excitation of which may be varied so as to modify the power-factor of the system, or through such modification to influence the load voltage. The function of a Synchronous Phase-Modifier is to supply reactive volt-amperes to the system with which it is connected.

CONSTRUCTIONAL CLASSIFICATION OF ROTATING MACHINES

Commutating Machines

76 **Direct-Current Commutating Machines** comprise a magnetic field of constant polarity, an armature, and a multisegmental commutator connected therewith. These include: Direct-Current Generators; Direct-Current Motors; Direct-Current Boosters; Direct-Current Motor-Generators and Dynamotors; Direct-Current Compensators or Balancers; and Arc Machines.

77 **Alternating-Current Commutating Machines*** comprise a magnetic field of alternating polarity, an armature, and multisegmental commutator connected therewith.

*Definitions of a-c. commutator-motors have not yet been agreed upon. The differences of opinion are fundamental and relate to the whole system to be employed in naming the numerous types. One example of this difference is in connection with the definition of the term " Repulsion-Motor", some desiring to extend its use to cover all a.c. commutator motors with short-circuited brushes, and others to substitute more systematic names for the various species of short-circuited brush motors.

78 **Synchronous Commutating Machines** include synchronous converters, cascade-converters, and double-current generators.

SYNCHRONOUS MACHINES

79 Comprise a constant magnetic field and an armature receiving or delivering alternating-currents in synchronism with the motion of the machine; *i.e.*, having a frequency strictly proportional to the speed of the machine. They may be sub-divided as follows:

80 **An Alternator** is a synchronous alternating-current generator, either single-phase or polyphase.

81 **A Polyphase Alternator** is a polyphase synchronous alternating-current generator.

82 **An Inductor Alternator is a Synchronous Alternator** in which both field and armature windings are stationary and in which masses of iron or inductors, by moving past the coils, alter the magnetic flux through them. It may be either singlephase or polyphase.

83 **A Synchronous Motor** is a machine structurally identical with a synchronous alternator, but operated as a motor.

INDUCTION MACHINES

84 Include apparatus wherein the primary and secondary windings rotate with respect to each other; *i.e.*, induction motors, induction generators, certain types of frequency converters and certain types of rotary phase-converters.

85 **An Induction Motor** is an alternating-current motor, either singlephase or polyphase, comprising independent primary and secondary windings, one of which, usually the secondary, is on the rotating member. The secondary winding receives power from the primary by electromagnetic induction.

86 **An Induction Generator** is a machine structurally identical with an induction motor, but driven above synchronous speed as an alternating-current generator.

87 **Unipolar or Acyclic Machines** are direct-current machines, in which the voltage generated in the active conductors maintains the same direction with respect to those conductors.

SPEED CLASSIFICATION OF MOTORS.

88 **Motors** may, for convenience, be classified with reference to their speed characteristics as follow:

89 *a*. **Constant-Speed Motors,** in which the speed is either constant or does not materially vary; such as synchronous motors, induction motors with small slip, and ordinary direct-current shunt motors.

90 *b*. **Multispeed Motors** (two-speed, three-speed, etc.), which can be operated at any one of several distinct speeds, these speeds being practically independent of the load, such as motors with two armature windings, or induction motors with controllers for changing the number of poles.

91 *c.* **Adjustable-Speed Motors,** in which the speed can be varied gradually over a considerable range, but when once adjusted remains practically unaffected by the load, such as shunt motors designed for a considerable range of field variation.

92 *d.* **Varying-Speed Motors,** or motors in which the speed varies with the load, ordinarily decreasing when the load increases; such as series motors, compound-wound motors, and series-shunt motors.

CLASSIFICATION OF ROTATING MACHINES RELATIVE TO THE DEGREE OF ENCLOSURE OR PROTECTION

93 The following types are recognized:

(1) Open
(2) Protected
(3) Semi-enclosed
(4) Enclosed
(5) Externally ventilated
(6) Water-cooled
(7) Self-ventilated
(8) Drip-proof
(9) Moisture-resisting
(10) Submersible
(11) Flame-proof
(12) Flame-proof slip-ring enclosure

94 No. 1. **An "open" machine** is of either the pedestal-bearing or end-bracket type where there is no restriction to ventilation, other than that necessitated by good mechanical construction.

95 No. 2. **A "protected" machine** is one in which the armature, field coils, and other live parts are protected mechanically from accidental or careless contact, while free ventilation is not materially obstructed.

96 No. 3. **A "semi-enclosed" machine** is one in which the ventilating openings in the frame are protected with wire screen, expanded metal, or other suitable perforated covers, having apertures not exceeding ¼ of a square inch (1.6 sq. cm.) in area.

97 No. 4. **An " enclosed " machine** is so completely enclosed by integral or auxiliary covers as to prevent a circulation of air between the inside and outside of its case, but not sufficiently tight to be termed air-tight.

98 No. 5. An **" externally ventilated " machine** has its ventilating air supplied by an independent fan or blower external to the machine.

99 No. 6. A **" water-cooled " machine** is one which mainly depends on water circulation for the removal of its heat.

100 No. 7. A **" self-ventilated " machine** differs from an externally ventilated machine only in having its ventilating air circulated by a fan, blower, or centrifugal device integral with the machine.

If the heated air expelled from the machine is conveyed away through a second pipe attached to the machine, this should be so stated.

101 No. 8. **A "drip-proof" machine** is one provided with ventila ing openings, so protected as to exclude falling moisture or dirt.

102 No. 9. A **moisture-resisting machine** is one in which all parts are treated with moisture-resisting material. Such a machine shall be capable of operating continuously or intermittently in a very humid atmosphere, such as in mines, evaporating rooms, etc.

103 No. 10. **A "submersible" machine** is a waterproof machine capable of withstanding complete submersion for four hours without injury.

104 No. 11. **A "flame-proof" machine** is a machine in which the enclosing case can withstand, without injury, any explosion of gas that may occur within it, and will not transmit the flame to any inflammable gas outside it.

105 No. 12. An induction motor in which the slip rings and brushes alone are included within a flame-proof case should not be described as a flame-proof machine, but as a machine "with **flame-proof slip-ring enclosure.**"

STATIONARY INDUCTION APPARATUS

107 **Stationary Induction Apparatus** changes electric energy to electric energy through the medium of magnetic energy without mechanical motion. It comprises several forms, distinguished as follows:

108 **Transformers**, in which the primary and secondary windings are ordinarily insulated one from another.

109 The terms **"high-voltage"** and **"low-voltage"** are used to distinguish the winding having the greater from that having the lesser number of turns. The terms **"primary"** and **"secondary"** serve to distinguish the windings in regard to energy flow, the primary being that which receives the energy from the supply circuit, and the secondary that which receives the energy by induction from the primary.

110 The **rated current of a constant-potential transformer** is that secondary current which, multiplied by the rated-load secondary voltage, gives the kv-a. rated output. That is, a transformer of given kv-a. rating must be capable of delivering the rated output at rated secondary voltage, while the primary impressed voltage is increased to whatever value is necessary to give rated secondary voltage.

The rated primary voltage of a constant-potential transformer is the rated secondary voltage multiplied by the turn ratio.

111 The **voltage ratio** of a transformer is the ratio of the r.m.s. primary terminal voltage to the r.m.s. secondary terminal voltage under specified conditions of load.

112 The "**current ratio**" of a current-transformer is the ratio of r.m.s. primary current to r.m.s. secondary current under specified conditions of load.

113 The **ratio of a transformer,** unless otherwise specified, shall be the ratio of the number of turns in the high-voltage winding to that in the low-voltage winding; *i.e.*, the "turn-ratio."

114 The "**marked ratio**" of an instrument transformer is the ratio which the apparatus is designed to possess under average conditions of use. When a precise ratio is required, it is necessary to specify the voltage, frequency, load and power factor of the load.

115 **Auto-transformers** have a part of their turns common to both primary and secondary circuits.

116 **Voltage Regulators** have turns in shunt and turns in series with the circuit, so arranged that the voltage ratio of the transformation or the phase relation between the circuit-voltages is variable at will. They are of the following three classes:

117 **Contact Voltage Regulators,** in which the number of turns in one or both of the coils is adjustable.

118 **Induction Voltage Regulators,** in which the relative positions of the primary and secondary coils are adjustable.

119 **Magneto Voltage Regulators,** in which the direction of the magnetic flux with respect to the coils is adjustable.

120 **Reactors** or **Reactance-Coils,** also called **Choke Coils**; a form of stationary induction apparatus used to supply reactance or to produce phase displacement.

INSTRUMENTS

121 **An Ammeter** is a measuring instrument, indicating in amperes.

122 **A Voltmeter** is a measuring instrument, indicating in volts.

123 **A Wattmeter** is an instrument for measuring electrical power, indicating in watts.

124 **Recording Ammeters, Voltmeters, Wattmeters, etc.,** are instruments which record graphically upon a time-chart the values of the quantities they measure.

125 **A Watt-hour Meter** is an instrument for registering watt-hours. This term is to be preferred to the term "integrating wattmeter."

126 **A Line-Drop Voltmeter Compensator** is a device in connection with a voltmeter, which causes the latter to indicate the voltage at some distant point of the circuit.

127 **A Synchroscope, sometimes called Synchronoscope,** is a device which, in addition to indicating synchronism, shows whether the machine to be synchronized is fast or slow.

STANDARDS FOR ELECTRICAL MACHINERY

128 NOTES. The expression " machinery " is here employed in a general sense in order to obviate the constant repetition of the words " machinery or induction apparatus."

129 All temperatures are to be understood as centigrade.

130 The expression " capacity " is to be understood as indicating " capability " except where specifically qualified as, for instance, in the case of allusions to electrostatic capacity, *i.e.*, capacitance.

131 Wherever special rules are given for any particular type of machinery or apparatus (such as railway motors, railway substation machinery, switches etc.) these special rules shall be followed, notwithstanding any apparent conflict with the provisions of the more general sections. In the absence of special rules on any particular point, the general rules on this point shall be followed.

132 **Objects of Standardization.** To ensure satisfactory results, electrical machinery should be specified to conform to the Institute Standardization Rules in order that it shall comply, in operation, with approved limitations in the following respects so far as they are applicable.

Operating temperature
Mechanical strength
Commutation
Insulation strength
Efficiency
Power factor
Wave shape
Regulation

133 **Capacity of an Electrical Machine.** So far as relates to the purposes of these Standardization Rules, the Institute defines the Capacity of an Electrical Machine as the load or task of which it is capable for a specified time (or continuously), without exceeding in any respect the limitations herein set forth.

Except where otherwise specified, the capacity of an electrical machine shall be expressed in terms of its *output*. For exceptions see §**140** and **418**.

134 **Rating of an Electrical Machine.** Capacity should be distinguished from Rating. The Rating of a machine is the output marked on the Rating Plate, and shall be based on, but shall not exceed, the maximum* load which can be taken from the machine under prescribed conditions of test. This is also called the rated output.

135 **A. I. E. E. and I. E. C. Ratings.** When the prescribed conditions of test are those of the A. I. E. E. Standardization Rules, the rating of the machine is the Institute Rating. When the prescribed conditions of the test are those of the I. E. C. Rules, the rating of the machine is the I. E. C. rating. A machine so rated in either case shall bear a distinctive sign upon its rating plate.

*The term " maximum load " does not refer to loads applied solely for mechanical, commutation, or similar tests.

136 **Standard Temperature and Barometric Pressure for Institute Rating.** The Institute Rating of a machine shall be its capacity when operating with a cooling medium of the ambient temperature of reference (40° for air or 25° for water, see **§153** and **157**) and with barometric conditions within the range given in **§156.** See **§168.**

UNITS IN WHICH RATING SHALL BE EXPRESSED

137 In the case of **Direct-Current Generators,** the rating shall be expressed in kilowatts (kw.) available at the terminals.

138 In the case of **Alternators** and **Transformers,** the rating shall be expressed in kilovolt-amperes (kv-a.) available at the terminals, at a specified power factor. The corresponding kilowatts shall also preferably be stated.

139 In the case of **Motors,** the rating shall be expressed in kilowatts* (kw.) available at the shaft. (An exception to this rule is made in the case of Railway motors, which for some purposes are also rated by their kilowatts ***input***, see **§418.**)

140 **Auxiliary machinery,** such as regulators, phase controllers, resistors, reactors, balancer sets, stationary and synchronous condensers, etc., shall have their ratings expressed in terms of the functions which they perform. It is essential to specify also the voltage of the circuits on which the machinery may appropriately be used.

KINDS OF RATING

141 There are two kinds of rating; namely, (1) rating for continuous service, *i.e.*, **continuous rating;** (2) rating for discontinuous service, *i.e.*, **short-time rating.**

142 **Continuous Rating.** A machine rated for continuous service shall be able to operate continuously at its rated output, without exceeding any of the limitations referred to in **§132.**

143 **Short-Time Rating.** A machine rated for short- ime service (*i.e.* service including runs alternating with stoppages of sufficient duration to ensure substantial cooling,) shall be able to operate at its rated output during a limited period, to be specified in each case, without exceeding any of the limitations referred to in **§132.** Such a rating is a **short-time rating.**

144 **Nominal Ratings.** For railway motors and railway substation machinery, certain nominal ratings are employed. See **§391** and **415.**

---

*Since the input of machinery of this class is measured in electrical units and since the output has a definite relation to the input, it is logical and desirable to measure the delivered power in the same units as are employed for the received power. Therefore, the output of motors should be expressed in kilowatts instead of in horse power. However, on account of the hitherto prevailing practise of expressing mechanical output in horse power, it is recommended that for machinery of this class the rating shall, for the present, be expressed both in kilowatts and in horse power; as follows:

kw.————h.p.————

The horse power rating of a motor may for practical purposes, be taken the as 4/3 of the kilowatt rating.

In order to lay stress upon the preferred future basis, it is desirable that on Rating Plates, the Rating in kilowatts shall be shown in larger and more prominent characters than the rating in horse power.

145 **Duty-Cycle Operation.** Many machines are operated on a cycle of duty which repeats itself with more or less regularity. For purposes of rating, either a continuous or a short-time "equivalent load" may be selected which shall simulate as nearly as possible the thermal conditions of the actual duty cycle.

146 **Standard durations of equivalent tests** shall be for machines operating under specified duty-cycles:

5 minutes
10 "
30 "
60 "
120 "
and continuous.

Of these the first five are short-time ratings selected as being thermally equivalent to the specified duty cycle.

When, for example, a short-time rating of 10 minutes duration is adopted, and the thermally equivalent load is 25 kw. for that period, then such a machine shall be stated to have a 10-minute rating of 25 kw.

147 In every case the equivalent short-time test shall commence only when the windings and other parts of the machine **are within 5°C of the ambient temperature** at the time of starting the test.

148 In the absence of any specification as to the kind of rating, the continuous rating shall be understood.*

Machines marked in accordance with **§135** shall be understood to have a continuous rating unless otherwise marked in accordance with **§146.**

HEATING AND TEMPERATURE

149 **Temperature Limitations of the Capacity of Electrical Machinery.** The capacity, so far as relates to temperature, is usually limited by the maximum temperature at which the materials in the machine, especially those employed for insulation, may be operated for long periods without deterioration. When the safe limits are exceeded, deterioration is rapid. The insulating material becomes permanently damaged by excessive temperature, the damage increasing with the length of time that the excessive temperature is maintained, and with the amount of excess temperature, until finally the insulation breaks down.

150 The result of operating at temperatures in excess of the safe limit is to shorten the life of the insulating material. This shortening of ife is, in certain special cases, warranted, when necessary for obtaining some other desirable result, as, for example, in some instances of railway motors, in providing greater power within a limited space. See **§419**. Exceptions may also be noted in the cases of contactors, arc-lamp magnet windings, etc., designed and constructed for operation at relatively high temperatures.

*An exception is made in the case of machines for railway service, where in the absence of of any specification as to the kind of rating, the "**nominal rating**" as defined in **§391** and **415** shall be understood.

151 There does not appear to be any advantage in operating at lower temperatures than the safe limits, so far as the life of the insulation is concerned. Insulation may break down from various causes, and generally, when these breakdowns occur, it is not due to the temperature at which the insulation has been operated, provided the safe limits have not been exceeded.

152 **The Ambient Temperature** is the temperature of the fluid or fluids which, coming into contact with the heated parts of a machine, carries off its heat convectively.

The cooling fluid may either be led to the machine through ducts, or merely surround the machine freely. In the former case the ambient temperature is to be measured at the intake of the machine. In the latter case see **§163.**

153 **Ambient Temperature of Reference for Air.** The standard ambient temperature of reference, when the cooling medium is air, shall be 40°C.

154 The permissible rises in temperature given in column 2 of the table in **§188** have been calculated on the basis of the standard ambient temperature of reference, by subtracting 40° from the highest temperatures permissible, which are given in column 1 of the same table.

155 A machine may be tested at any convenient ambient temperature, but whatever be the value of this ambient temperature, the permissible rises of temperature must not exceed those given in column 2 of the table in **§188.**

156 **Altitude.** Increased altitude has the effect of increasing the temperature rise of some types of machinery. In the absence of information in regard to the height above sea level at which the machine is intended to work in ordinary service, this height is assumed not to exceed 1000 meters (3300 feet.) For machinery operating at an altitude of 1000 meters or less, a test at any altitude less than 1000 meters is satisfactory, and no correction shall be applied to the observed temperatures. Machines intended for operation at higher altitudes shall be regarded as special. When a machine is rated for service at altitudes above 1000 meters (3300 ft.) the normal permissible temperature rise, until more nearly accurate information is available, shall be reduced by 1 per cent for each 100 meters (330 ft.) by which the altitude exceeds 1000 meters. Water-cooled oil transformers are exempt from this reduction.

157 **Ambient Temperature of Reference for Water-Cooled Machinery.** For water-cooled machinery, the standard temperature of reference for incoming cooling water shall be 25° C, measured at the intake of the machine.

158 **In Testing Water-Cooled Transformers,** it is important, especially for the smaller sizes, to maintain the temperature of the ingoing water within 5°C. of the surrounding air. Where this is impracticable, the reference ambient temperature shall be taken as that indicated by the resistance of the windings, when the disconnected transformer is being

supplied with the normal amount of cooling water and the temperature of the windings has become constant.

159 **Machinery Cooled by Air led to the machine from a distance through ventilating ducts.** In this case the temperature of the ingoing air shall be measured at the intake of the machine. The ambient temperature shall be determined in the manner specified in **§158** for water-cooled transformers.

160 In the case of **rotating machines,** the above method becomes inapplicable, and recourse must be had to a weighted mean between the temperatures of the circulating air and of the surrounding air. If the necessary thermal data are known, this weighted mean can be calculated; but it shall be permitted to employ a conventional weighted mean, by giving a weight of four to the circulating air and of one to the surrounding room air, provided that these two temperatures during the test do not differ by more than 10°C.

161 **Machines Cooled by Other Means.** For machines cooled by other means, special rules are necessary.

162 **Outdoor Machinery Exposed to Sun's Rays.**

Outdoor machinery not protected from the sun's rays at times of heavy load, must receive special consideration as regards ambient temperature.

163 **Measurement of the Ambient Temperature During Tests of Machinery.**

The ambient temperature is to be measured by means of several thermometers placed at different points around and half-way up the machine at a distance of 1 to 2 meters (3 to 6 feet), and protected from drafts, and abnormal heat radiation, preferably as in **§165.**

164 The value to be adopted for the ambient temperature during a test, is the mean of the readings of the thermometers (placed as above) taken at equal intervals of time during the last quarter of the duration of the test.

165 Inorder to avoid **errors due to the time lag** between the temperature of large machines and the variations in the ambient air, all reasonable precautions must be taken to reduce these variations and the errors arising therefrom. Thus, the thermometer for determining the ambient temperature shall be immersed in a suitable liquid, such as oil, in a suitable heavy metal cup. This can be made to respond to various rates of change, by proportioning the amount of oil to the metal in the containing cup. A convenient form for such an oil-cup consists of a massive metal cylinder with a hole drilled partly through it. This hole is filled with oil and the thermometer is placed therein with its bulb well immersed. The larger the machine under test, the larger should be the metal cylinder employed as an oil-cup in the determination of the ambient temperature. The smallest size of oil cup employed in any case shall consist of a metal cylinder 25 mm. in diameter and 50 mm. high (1 in. in diameter and not less than 2 in. high).

166 **In Testing Transformers** and sometimes other machines it will often be desirable to avoid errors due to time lag in temperature changes by

employing an idle unit of the same size and subjected to the same conditions of cooling as the unit under test, for obtaining the ambient temperature as described in § **158** and § **159**.

167 Where **machines are partly below the floor line** in pits, the temperature of the rotor shall be referred to a weighted mean of the pit and room temperatures, the weight of each being based on the relative proportions of the machine in and above the pit. Parts of the stator constantly in the pit shall be referred to the ambient temperature in the pit.

168 **Corrections for the Deviation of the Ambient Temperature, at the time of test, from the reference value of 40°C.** In view of numerous experiments which have shown that the effect on the temperature rise of the precise value of the ambient temperature at the time of test, is small, obscure and of doubtful direction, no correction shall be made for ambient temperature deviations from the standard value of 40°C. It is, however, desirable that tests should be conducted at ambient temperatures not lower than 25°C. Exception to this rule is made in the case of air-blast transformers, in which, if the ingoing air temperature during the test differs from 40°C, correction on account of difference in resistance and difference in convection shall be made by changing the "observable" temperature rise of the windings by 0.5% for each degree centigrade. Thus with a room temperature of 30 deg. cent. the "observable" rise of temperature shall be increased by 5 per cent, and with a room temperature of 15 deg. cent. the "observable" rise of temperature shall be increased by 12.5 per cent.

169 **Duration of Heat Run.** For practical purposes, the duration of a test of a machine for continuous service shall be prolonged until the difference between the temperature of the machine and the ambient temperature is practically constant. Temperature measurements, when possible, shall be taken during operation, as well as when the machine is stopped. The highest figures thus obtained shall be adopted. In order to abridge the long heating period, in the case of large machines, reasonable overloads of current during the preliminary period are suggested for them.

OPERATING TEMPERATURES

170 The actual temperatures attained in the different parts of a machine, and not the rises in temperature, affect the life of the insulation of the machine. (See §**149** to **151**).

171 The temperatures in the different parts of a machine which it is desired to ascertain, are the maximum temperatures reached in those parts.

172 As it is usually impossible to determine the maximum temperature attained in insulated windings, it is convenient to apply a correction to the measured temperature, to approximate the difference between the actual maximum temperature and the measured temperature by the method used. This correction or margin of security is provided to cover the errors due to fallibility in the location of the measuring devices, as well as inherent inaccuracies in measurement and methods.

TEMPERATURE MEASUREMENTS

173 In determining the temperature of different parts of a machine, three methods will be considered. One or other of these methods, as set forth below, will usually be appropriate for commercial measurements on any particular type of machine.

174 **Method No 1. Thermometer Method.**
This method consists in the determination of the temperature by mercury or alcohol thermometers, by resistance thermometers, or by thermocouples, any of these instruments being applied to the hottest accessible part of the ***completed*** machine, as distinguished from the thermocouples or resistance coils imbedded in the machine as described under Method No. 3.

175 When Method No.1 is used, the hottest-spot temperature shall be estimated by adding a hottest-spot correction of 15°C to the highest temperature observed.

176 *Exception*. In cases where the thermometer is applied directly to the surface of a bare winding, such as an edgewise strip conductor, or a copper casting, a hottest-spot correction of 5°C. instead of 15°C shall be made, in order to allow for the unlikelihood of locating the thermometer at the hottest spot.

177 **Method No. 2. Resistance Method.**
This method consists in the measurement of the temperature of windings by their increase in resistance, corrected* to the instant of shut-down when necessary. In the application of this method careful thermometer measurements must also be made whenever practicable without disassembling the machine, † in order to increase the probability of revealing the highest observable temperature. Whichever method yields the higher temperature, that temperature shall be taken as the "highest observable" temperature and a hottest-spot correction of 10°C added thereto.

178 In the case of resistance measurements, the temperature co-efficient of copper shall be deduced from the formula $1/(234.5 + t)$. Thus, at an initial temperature $t = 40°$ C. the temperature co-efficient or increase in resistance per degree centigrade rise is $1/(274.5) = 0.00364$. The following table, deduced from the formula, is given for convenience of reference.

---

*Whenever a sufficient time has elapsed between the instant of shut-down and the time of the final temperature measurement to permit the temperature to fall, suitable corrections shall be applied, so as to obtain as nearly as practicable the temperature at the instant of shut-down. This can sometimes be approximately effected by plotting a curve, with temperature readings as ordinates and time as abscissas, and extrapolating back to the instant of shut-down. In other instances, acceptable correction factors can be applied.

In cases where successive measurements show *increasing* temperatures after shut-down, the highest value shall be taken.

†As one of the few instances in which the thermometer check cannot be applied in Method No. 2, the rotor of a turbo-alternator may be cited.

Temperature of the winding, in degrees C. at which the initial resistance is measured.	Increase in resistance of copper per ohm per °C.
0	0.00 427
5	0.00 418
10	0.00 409
15	0.00 401
20	0.00 393
25	0.00 385
30	0.00 378
35	0.00 371
40	0.00 364

179 In **Field Coils of Low Resistance,** where the joints and connections form a considerable part of the total resistance, the measurement of temperature by the resistance method shall not be used.

180 **The Temperature of the Windings of Transformers** is always to be ascertained by Method 2. In the case of air-blast transformers, it is especially important to place thermometers near the air outlet.

182 **Method No. 3. Imbedded Temperature-Detector Method.**

Thermocouples or resistance coils, located as nearly as possible at the estimated hottest spot. This method is only to be used with coils placed in slots.

183 **By Building into the Machine** suitably placed thermocouples or resistance coils, a temperature not much less than that of the hottest spot will be disclosed. When these devices are adopted for such temperature determinations, a liberal number shall be employed, and and all reasonable efforts consistent with safety shall be made to locate them at the various places where the highest temperatures are likely to occur.

184 **Temperature-Detectors** should be placed in at least two sets of locations. One of these should be between coil and core, and one between the top and bottom coils, where two coils per slot are used. Where only one coil per slot is used, one set of detectors shall be placed between coil and core, and one set between coil and wedge.

185 Method No. 3 should be applied to all stators of machines with wide cores (50 cm.—20 in.—and over) and to all machines of 5000 volts and over, if of over 500 kv-a., regardless of core width.

186 Correction Factor for this Method—On two-layer machines with couples between coils, and between coil and slot, add 5° to the highest

reading. In single-layer machines with couples between coil and core and between coil and wedge, add to the highest reading 10° C. plus 1° C. per 1000 volts above 5000 volts of terminal pressure.

TEMPERATURE LIMITS

187 The following table gives the limits for the hottest-spot temperatures of insulations. The permissible limits are indicated in column 1 of the table. The limits of temperature rise permitted under rated-load conditions are given in column 2, and are found by subtracting 40° C. from the figures in column 1. Whatever be the ambient temperature at the time of the test, the rise of temperature observed must never exceed the limits in column 2 of the table. The highest temperatures attained in any machine corresponding to the output for which it is rated must not exceed the values indicated in column 1 of the table and clauses following.

188 **Table of Hottest-Spot Temperatures and of Corresponding Permissible Temperature Rises.**

Class	Description of Insulation	Column 1 Highest permissible temperatures for hottest spot	Column 2 Highest permissible temperature rise of hottest spot above 40° for the purpose of fixing the Institute Rating.
A1	Cotton, silk, paper and other fibrous materials, not so treated as to increase the thermal limit.	95°C	55°C
A2	Similar to A1, but treated or impregnated and including enameled wire.	105°C	65°C
B	Mica, asbestos or other material capable of resisting high temperatures, in which any Class A material or binder, if used, is for structural purposes only, and may be destroyed without impairing the insulating or mechanical qualities.	125°C	85°C

189 NOTE. The Institute recognizes the ability of manufacturers to employ Class B insulation successfully at maximum temperatures of 150° C. and even higher. However, as sufficient data covering experience over a period of years at such temperatures is at present unavailable, the Institute adopts 125° C as a conservative limit for this class of insulation, and any increase above this figure should be the subject of special guarantee by the manufacturer.

190 Class C. For fireproof and refractory materials such as pure mica, porcelain, etc., no limit is specified.

191 When a lower-temperature class material is comprised in a completed product to such an extent, or in such ways, that its subjection

to the temperature limits allowed for the higher-temperature class material, with which it is associated, would affect the integrity of the insulation either mechanically or electrically, the permissible temperature shall be fixed at such a value as shall afford ample assurance that no part of the lower-temperature class material shall be subjected to temperatures higher than those approved by the Institute and set forth above. See also **§150**.

192 **Table Summarizing the Temperature Conditions under the Three Preceding Methods of Measurement for Insulations of Classes A_1, A_2 and B.** (See next page)

SPECIAL CASES OF TEMPERATURE LIMITS

193 **Temperature of Oil.** The oil in which apparatus is immersed shall in no part be subjected to an observable temperature in excess of 90°C.

194 **Water-Cooled Transformers.** In these the hottest-spot temperature shall not exceed 85°C.

195 **Railway Motor Temperature Limits,** see **§419.**

196 **Squirrel-Cage and Amortisseur Windings.** In many cases the insulation of such windings is largely for the purpose of making the conductors fit tightly in their slots, and the slightest effective insulation is ample. In other cases, there is practically no insulating material on the windings. Consequently, the temperature rise may be of any value such as will not occasion mechanical injury to the machine.

197 **Collector Rings.** The temperature of collector rings shall not be permitted to exceed the "hottest-spot" values set forth in **§188** for the insulations employed either in the collector rings themselves, or in adjacent insulations whose temperatures would be affected by the heat from the collector rings. The temperature of the rings shall in no case exceed 130°C.

198 **Commutators.** For commutators so constructed that no difficulties from expansion can occur, the following temperature limits are prescribed:—

Current per Brush Arm	Maximum Permissible Temp.
200 amperes or less	130°C.
200 to 900 amperes	130°C. less 5 deg. for each 100 amperes increase above 200.
900 amperes and over	95°C.

In no case shall the observable temperature be permitted to exceed the values given in **§188** for the insulation employed, either in the commutator or in any insulation whose temperature would be affected by the heat of the commutator.

199 **Cores.** The temperature of the iron core in contact with the windings must not exceed the limits of temperature and temperature rise permitted for the windings themselves.

200 **Other parts,** (such as brush-holders, brushes, bearings, pole-tips, cores, etc.) All parts of electrical machinery other than those

Class	Permissible Hottest Spot Temp.	METHOD I THERMOMETER ONLY			METHOD II RESISTANCE (With thermometer check when practicable)			METHOD III IMBEDDED THERMOCOUPLES OR RESISTANCE COILS								
								Double-Layer windings For all voltages			Single-Layer windings 5000 volts or less			Single-Layer Windings above 5000 volts		
		Hottest-Spot Correction	Limiting Observable Temp.	Limiting Temp. Rise above 40°	Hottest-Spot Correction	Limiting Observable Temp.	Limiting Temp. Rise above 40°	Hottest-Spot Correction	Limiting Observable Temp.	Limiting Temp. Rise above 40°	Hottest-Spot Correction.	Limiting Observable Temp.	Limiting Temp. Rise above 40°	Hottest Spot Correction	Limiting Observable Temperature	Limiting Temp. Rise above 40°
A_1	95°	15	80	40	10	85	45	5	90	50	10	85	45	10 + (E-5)*	85 - (E-5)	45 - (E-5)
A_2	105°	15	90	50	10	95	55	5	100	60	10	95	55	10 + (E-5)	95 - (E-5)	55 - (E-5)
B	125°	15	110	70	10	115	75	5	120	80	10	115	75	10 + (E-5)	115 - (E-5)	75 - (E-5)

*In this formula *E* represents the rated pressure between terminals in kilovolts. Thus for a three-phase machine of 11 kilovolts between terminals the hottest-spot correction to be added to the maximum observable temperature will be 16°C.

whose temperature affects the temperature of the insulating material, may be operated at such temperatures as shall not be injurious in any respect. But no part of continuous-duty machinery subject to handling in operation, such as brush-rigging, shall have a temperature in excess of 100°C. for more than a very brief time.

ADDITIONAL REQUIREMENTS

Short-Circuit Stresses.

201 The Institute recognizes the self-destructibility, both mechanical and thermal, of certain sizes and types of machines, when subjected to severe short-circuits, and recommends that ample protection be provided in such cases, external to the machine if necessary.

Over-Speeds.

202 All types of rotating machines shall be so constructed that they will safely withstand an over-speed of 25 per cent, except in the case of steam turbines, which, when equipped with emergency governors, shall be constructed to withstand 20 per cent over-speed.

In the case of series motors, it is impracticable to specify percentage values for the guaranteed over-speed, on account of the varying service conditions.

Water-wheel generators shall be constructed for the maximum runaway speed which can be attained by the combined unit.

Momentary Loads.

203 Machines shall be required to carry momentary loads of 150 per cent rated load, and commutating machinery shall commutate successfully under this condition. Successful commutation is such that neither brushes nor commutator are injured by the test.

Machines for duty-cycle operat on shall be rated according to their equivalent load, either on the short-time or continuous basis, but intended for operation with widely fluctuating loads, shall commutate successfully under their specified operating conditions. See § **139.**

Stalling Torque of Motors

204 Motors for continuous service shall, except when otherwise specified, be required to develop a running torque at least 175 per cent of that corresponding to the running torque at their rated load without stalling.

Obviously, duty-cycle machines must carry their peak loads without stalling.

WAVE FORM

205 The **Sine Wave** shall be considered as standard except where deviation therefrom is inherent in the operation of the machine.

206 **The deviation of wave form** from the sinusoidal is determined by superposing upon the actual wave, (as determined by oscillograph), the equivalent sine wave of equal length, in such a manner as to give the least difference, and then dividing the maximum difference between corresponding ordinates by the maximum value of the equivalent sine wave. A maximum deviation of the wave from sinusoidal shape not exceeding 10% is permissible, except when otherwise specified.

EFFICIENCY AND LOSSES

207 **Machine Efficiency** is the ratio of the power delivered by the machinery to the power received by it.

208 **Plant Efficiency** is the ratio of the energy delivered from the plant to the energy received by it in the same period of time,* the period of time to be suitably chosen.

209 **Conventional Efficiency** of machinery is the ratio of the output to the sum of the output and the losses; or of the input minus the losses to the input; when, in either case, conventional values are assigned to one or more of these losses. The need for assigning conventional values to certain losses, arises from the fact that some of the losses in electrical machinery are practicably indeterminable, and must, in many cases, either be approximated by an approved method of test, or else values recommended by the Institute and designated "conventional" values shall be employed for them in arriving at the "conventional efficiency." Efficiencies based upon conventional losses shall be specifically stated to be conventional efficiencies.

210 **Efficiency Determination.** Input and output determination of efficiency may be made directly, measuring the output by brake, or equivalent, where applicable. Within the limits of practical application the circulating power method, sometimes described as the Hopkinson or "loading back" method, may be used; in machines where none of these methods are practicable the conventional efficiency should be used, especially in the case of large machines of high efficiency.

211 Values for the indeterminate losses may also be obtained by brake or other accurate test, and used in estimating actual efficiencies of similar machines, by the separate-loss method.

212 **Normal Conditions.** The efficiency shall correspond to, or be corrected to, the normal conditions herein set forth, which shall be regarded as standard. These conditions include voltage, current, power-factor, frequency, wave-shape, speed, temperature, or such of them as may apply in each particular case.

213 **Measurement of Efficiency.** Electric power shall be measured at the terminals of the apparatus. In polyphase machines, sufficient measurements shall be made on all phases to avoid errors of unbalance.

214 **Point at Which Mechanical Power Shall be Measured.** Mechanical power delivered by machines, shall be measured at the pulley, gearing, or coupling, on the rotor shaft, thus excluding the loss of power in the belt or gear friction. See, however, **§415**.

215 **The Efficiency of Alternating-Current Apparatus** shall be measured when the current is in phase with the terminal voltage, unless otherwise specified, or unless a definite phase difference is inherent in the apparatus, as in induction machinery.

216 **Efficiency of Alternating-Current Apparatus in regard to Wave Shape.** In determining the efficiency of alternating-current apparatus, the sine wave is to be considered as standard, unless a different wave form is inherent in the operation of the apparatus. See **§205**.

*An exception should be noted in the case of the efficiency of storage batteries.

217 Temperature of Reference for Efficiency Determinations. The efficiency, at all loads, of all apparatus, shall be determined at, or corrected to, a reference temperature of 75°C.

218 The losses in constant-potential machinery, either of the stationary type, or of the constant-speed rotary type, are of two classes; namely, those which remain substantially constant at all loads, and those which vary with the load. The former include iron losses, windage and friction, also I^2R losses in any shunt windings. The latter include I^2R losses in series windings. The constant losses may be determined by measuring the power required to operate the machine at no load, deducting any series I^2R losses. The variable loss at any load may be computed from the measured resistance of the series windings and the given load current.

219 Stray Load Losses. The above simple method of determining the losses and hence the efficiency is only approximate, since the losses which are assumed to be constant do actually vary to some extent with the load, and also because the actual loss in the copper windings is sometimes appreciably greater than the calculated I^2R loss. The difference between the approximate losses as above determined and the actual losses is termed the "stray load losses"*. These latter are due to distortions in electric or magnetic fluxes from their no-load distributions or values, brought about by the load current. They are usually only approximately measurable or may be indeterminable.

220 Table of Losses. Losses in apparatus may be classified as follows:

Accurately Measurable or Determinable	*Approximately Measurable or Determinable*	*Indeterminable*
a. No-Load Core Losses including eddy-current losses in conductors at no-load	*c.* Brush Friction Loss	*h.* Iron Loss due to flux distortion.
b. Load I^2R in windings No-Load I^2R " "	*d.* Brush-Contact	*i.* Eddy-Current losses in conductors due to transverse fluxes occasioned by the load currents.
	e. Losses due to windage and to bearing friction	*k.* Eddy-Current losses in conductors due to tooth saturation resulting from distortion of the main flux.
	f. Extra copper loss in transformer windings, due to stray fluxes caused by load currents	*l.* Tooth-frequency losses due to flux distortion under load.
	g. Dielectric Losses.	*m.* Short-Circuit Loss of Commutation.

*In the Table of § 220, stray load losses include f, h, i, k, l and m; but do not include increased core losses due to increased excitation for compensating internal drop under load.

221 **Evaluation of Losses.** The larger individual losses are either accurately or approximately determinable, but certain of the indeterminable losses reach values in various kinds of machinery which require that they should be taken into account.

Methods of measuring, approximating or allowing for these various losses are given below.

LOSSES TO BE TAKEN INTO ACCOUNT IN VARIOUS TYPES OF MACHINES

222 **Continuous-Current Commutating Motors and Generators.**

No-load core losses (Acc. Meas. or Deter.)

I^2R loss in windings (" " " ")

Brush contact I^2R loss. (Approximately Meas. or Deter) Unless otherwise specified, use the Institute Standard of 1 volt for contact drop per brush;—*i. e.*, 2 volts for total brush drop—for either carbon or graphite brushes. See **§232** and **429**.

Friction of bearings and windage (Approx. Meas. or Deter.)

Rheostat losses, when present (Acc. Meas. or Deter.)

Brush friction (Approx. Meas. or Deter.)

All indeterminable load losses, (including stray-load iron losses) which may be important, which vary with the design, and for which no satisfactory method of determination has been found, shall be included as zero per cent in estimating conventional efficiency.

223 **Synchronous Motors and Generators.**

No-load core losses. (Acc. Meas. or Deter.)

I^2R loss in windings. " " " " based upon rated kw. and power factor.

Stray load-losses. (Indeterminable.) In approximating these losses, the method described in **§236** shall be employed.

Friction of bearings and windage. (Approx. Meas. or Deter.)

(Brush friction and brush-contact loss is negligible.)

Rheostat losses, when present. (Acc. Meas. or Deter.) corresponding to rated kw. and power factor.

224 **Induction Machines.**

No-load core losses. (Acc. Meas. or Deter.)

I^2R losses in windings. " " " "

Stray load-losses (Indeterminable.) In approximating these losses the method described in §240 shall be employed.

Brush friction when collector rings are present. (Approx. Meas. or Deter.)

Brush contact loss. (Approximately Meas. or Deter.). Unless otherwise specified, use the Institute Standard of 1 volt for contact drop per brush;—for either carbon or graphite brushes. See **§232**.

Friction of bearings and windage. (Approx. Meas. or Deter.)

225 **Commutating A-C. Machines**

No-load core losses. (Acc. Meas. or Deter.)
I^2R losses in windings. (" " " ")
Brush friction. (Approx. Meas. or Deter.)
Brush contact loss. (Approx. Meas. or Deter.) Unless otherwise specified, use the Institute Standard of 1 volt for contact drop per brush;—for either carbon or graphite brushes. See **§232** and **429**.
Friction of bearings and windage. (Approx. Meas. or Deter.)

Short-Circuit loss of commutation. (Indeterminable.) Iron loss due to flux distortion. (Indeterminable.) Eddy current losses due to fluxes varying with load and saturation. (Indeterminable.)	The Institute is not at this time prepared to make recommendations for approximating these losses.

226 **Synchronous Converters.**

No-load core losses. (Acc. Meas. or Deter.)
I^2R losses in windings. (Approx. " " ") based on rated kw. and power factor.
Brush friction. (Approx. Meas. or Deter.)
Brush contact loss. (Approx. Meas. or Deter.) Unless otherwise specified, use the Institute Standard of 1 volt for contact drop per brush;—for either carbon or graphite brushes. See **§232.**

Short-circuit loss of commutation (Indeterminable) Iron loss due to flux distortion when present. (Indeterminate. Eddy-current losses due to fluxes varying with load and saturation. (Indeterminable.	These losses, while usually of low magnitude, are erratic, and the Institute is not at this time prepared to make recommendations for approximating them.

Friction of bearings and windage. (Approx. Meas. or Deter.)
For the booster type of synchronous converter, where the booster forms an integral part of the unit, its losses shall be included in the total converter losses in estimating the efficiency.

227 **Transformers.** No-load losses. These include the core loss and the I^2R loss due to the exciting current (Acc. Meas. or Deter.) and the dielectric hysteresis loss in the insulation (Approx. Meas. or Deter.) At low power factors the total losses due to treating the exciting current in this way are likely to be too low.

Load losses. These include I^2R loss in windings, and eddy-current losses in windings and core due to fluxes varying with load. (Approx. Meas. or Deter.) See **§240** for the method of approximating these losses.

DETERMINATION OR APPROXIMATION OF LOSSES IN ROTATING MACHINERY

228 **Bearing Friction and Windage** may be determined as follows: Drive the machine from an independent motor, the output of which shall be suitably determined. The machine under test shall have its brushes removed and shall not be excited. This output represents the bearing friction and windage of the machine under test.

In the case of engine-type generators, one-half the output of the driving motor shall be charged against the generator for windage. The remainder, considered as bearing friction, shall be debited to the prime mover.

229 **Brush Friction of Commutator and Collector Rings.** Follow the test of **§228,** taking an additional reading with the brushes in contact with the commutator or collector rings. The difference between the output obtained in the test in **§228** and this output shall be taken as the brush friction. Note: The surface of commutator and brushes should already be smooth and glazed from running when this test is made.

230 **No-Load Core Loss.** Follow the test in **§229** with an additional reading having the machine excited. The difference between the output value of **§229** and the output value of this reading shall be taken as the no-load core loss. This no-load core loss shall be taken with the machine excited, so as to produce rated terminal voltage.

231 **No-Load Core Loss at the Internal Voltage Corresponding to Rated Load.** This shall be taken as in **§230,** except that the machine shall be excited so as to produce at the terminals the voltage corresponding to the calculated internal voltage for the load and power factor under consideration. For synchronous machines, since no generally accepted method has been determined for obtaining the stator reactance, the internal voltage shall be determined by adding resistance drop to the terminal voltage.

232 **Brush Contact Loss** depends largely upon the material of which the brush is composed. As indicating the range of variation the following table will be of interest:

Grade of Brush	Volts drop across one brush-contact. (Average of positive and negative brushes)
Hard Carbon	1.1
Soft Carbon	0.9
Graphite	0.5 to 0.8
Metal-Graphite types	0.15 to 0.5 (The former for largest proportion of metal)

One volt drop per brush shall be considered as the Institute Standard drop corresponding to the I^2R brush-contact loss, for carbon and graphite brushes. Metal-graphite brushes shall be considered as special. See **§429.**

233 **Field-Rheostat Losses** which are normally present shall be included in the generator losses where there is a field rheostat in series with the field magnets of the generator, even when the machine is separately excited.

234 **Ventilating Blower.** When a blower is supplied as part of the machine set, the power required to drive it shall be charged against the machine set; but not against the machine.

235 **Losses in Other Auxiliary Apparatus.** Auxiliary apparatus, such as a separate exciter for a generator or motor, shall have its losses charged against the plant of which the generator and exciters are a part, and not against the generator.

236 **Stray Load Losses in Synchronous Generators and Motors.** These include iron losses and eddy-current losses in the copper due to fluxes varying with load and due to saturation.

Stray load-losses are to be determined by operating the machine on short circuit and at rated-load current. This, after deducting the windage and friction and I^2R loss, gives the stray load-loss for polyphase generators and motors. These losses in single-phase machines are large; but the Institute is not yet prepared to give a method for measuring them.

237 **Stray Load-Losses in Induction Machines.**

These include eddy-current losses in the stator copper, and other eddy-current losses due to fluxes varying with the load. In wire wound machines these are usually negligible.

With rotor removed and for a given stator current, measure the input through the stator at different frequencies. Plot a curve of loss against frequency. At low frequencies, the loss becomes constant, indicating the I^2R value. The difference between this I^2R value and the total loss at normal frequency shall be taken as the stray load-loss. This method is not accurate with induction motors in which the slots are entirely closed. In such machines these losses may be greater.

238 **Induction Motor Rotor I^2R Loss.** This should be determined from the slip whenever the latter is accurately determinable, using the following equation:

$$\text{Rotor } I^2R \text{ loss} = \frac{\text{Output} \times \text{slip}}{1 - \text{slip}}$$

In large slip-ring motors, in which the slip cannot be directly measured by loading, the rotor I^2R loss shall be determined by direct resistance measurement; the rotor full-load current to be calculated by the following equation:

$$\text{Current per ring} = \frac{\text{watts output}}{\text{Rotor voltage at stand-still} \times \sqrt{3} \times K}$$

This equation applies to three-phase rotors. For rotors wound for two phase, use 2 instead of the $\sqrt{3}$. K may be taken as 0.95

for motors of 150 kw. or larger. The factor K usually decreases as the size of motor is reduced, but no specific value can be stated for smaller sizes.

DETERMINATION OR APPROXIMATION OF LOSSES IN TRANSFORMERS

239 **No-Load Losses.** These shall be measured with open secondary circuit at the rated frequency, and with an applied primary voltage giving the rated secondary voltage plus the IR drop which occurs in the secondary under rated-load conditions. These no-load losses include core losses, consisting of hysteresis and eddy-current losses in the core, as well as dielectric loss in insulation due to electrostatic flux, which latter loss increases rapidly with temperature, and the test should therefore preferably be made at the reference temperature of 75°C.

240 **Stray Load-Losses.** These shall be measured by applying a primary voltage sufficient to produce rated-load current in the primary and secondary windings, the latter being short circuited. The stray load-losses will then be equal to the input decreased by the measured I^2R losses in both windings. It is ordinarily immaterial whether the high-voltage or low-voltage winding is used as the primary winding in this test.

241 **Volt-Ampere Ratio of Transformers.**
The volt-ampere ratio which should not be confused with real efficiency, is the ratio of the volt-ampere output to the volt-ampere input of a transformer, at any given power factor.

242 **Methods of Loading Transformers for Temperature Tests.**
Wherever practicable, transformers should be tested under conditions that will give losses approximating as nearly as possible to those obtained under normal or specified load conditions, maintained for such a time as is necessary for the temperature to reach a steady value. The maximum temperature rises measured during this test should be considered as the observable temperature rises for the given load.

An approved method of making these tests is the "**loading back**" method. The principal variations of this method are—

243 (a) **With duplicate single-phase transformers.**
Duplicate single-phase transformers may be tested in banks of two, with both primary and secondary windings connected in parallel. Normal magnetizing voltage should then be applied and the required current circulated from an auxiliary source. One transformer can be held under normal voltage and current conditions while the other may be operating under slightly abnormal conditions.

244 (b) **With one three-phase transformer.**
One three-phase transformer may be tested in a manner similar to (a), provided the primary and secondary windings are each connected in delta for the test. Normal three-phase magnetizing volt

age should be applied and the required current circulated from an auxiliary single-phase source.

245 (c) **With three single-phase transformers.**

Duplicate single-phase transformers may be tested in banks of three, in a manner similar to (b) by connecting both primary and secondary windings in delta and applying normal three-phase magnetizing voltage and circulating the required current from an auxiliary single-phase source.

246 NOTE:— Among other methods that have a limited application and can be used only under special conditions may be mentioned—

(1) Applying dead load by means of some form of rheostat.

(2) Running alternately for certain short intervals of time on open circuit and then on short circuit, alternating in this way until the transformer reaches steady temperature.

In this test the voltage for the open-circuit interval and the current for the short-circuit interval shall be such as to give the same integrated core loss, and the same integrated copper loss, as in normal operation.

DIELECTRIC TESTS OF MACHINERY

247 **Basis for Determining Test Voltages.** The test voltage which shall be applied to determine the suitability of insulation for commercial operation is dependent upon the kind and size of the machinery, and its normal operating voltage, upon the nature of the service in which it is to be used, and upon the severity of the mechanical and electrical stresses to which it may be subjected. The voltages and other conditions of test which are recommended, have been determined as reasonable and proper for the great majority of cases and are proposed for general adoption, except when specific reasons make a modification desirable.

248 **Condition of Machinery to be Tested.** Commercial tests shall, in general, be made with the completely assembled machinery and not with individual parts. The machinery shall be in good condition, and high-voltage tests, unless otherwise specified, shall be applied before the machine is put into commercial service, and shall not be applied when the insulation resistance is low owing to dirt or moisture. High-voltage tests shall be made at the temperature assumed under normal operation. High-voltage tests to determine whether specifications are fulfilled, are admissible on new machines only. Unless otherwise agreed upon, high-voltage tests of a machine shall be understood as being made at the factory.

249 **Points of Application of Voltage.** The test voltage shall be successively applied between each electric circuit and all other electrical circuits and metal parts grounded.

250 **Interconnected Polyphase Windings** are considered as one circuit. All windings of a machine except that under test, shall be connected to ground.

251 **Frequency, Wave Form and Test Voltage.** The frequency of the testing circuit shall not be less than the rated frequency of the apparatus tested. A sine-wave form is recommended. See **§205.** The test shall be made with alternating voltage having a crest value equal to the $\sqrt{2}$ times the specified test voltage.

252 **Duration of Application of Test Voltage.** The testing voltage for all classes of apparatus shall be applied continuously for a period of 60 seconds.

253 **Apparatus for Use on Single-Phase, 3-Phase-Delta or 3-Phase-Star Circuits.** Apparatus, such as transformers, which may be used either on single-phase circuits, or in star or delta connection on three-phase circuits, shall have the maximum voltage of the circuits on which they may be used indicated on the rating plate and the test shall be based on such maximum voltage.

VALUES OF TEST VOLTAGES

254 **The Standard Test for All Classes of Appa atus, Except as Otherwise Specified, Shall be Twice the Normal Voltage of the Circuit to Which the Apparatus is Connected, Plus 1000 Volts.**

255 *Exception*—**Alternating-Current Apparatus connected to Permanently Grounded Single-Phase Circuits, for use on Permanently Grounded Circuits of more than 300 Volts** shall be tested with 2.73 times the voltage of the circuit to ground + **1000** volts.

256 *Exception*—**Distributing Transformers.** Transformers for primary pressures from 550 to 5000 volts, the secondaries of which are directly connected to consumers' circuits and commonly known as distributing transformers, shall be tested with 10,000 volts from primary to core and secondary combined. The secondary windings shall be tested with twice their normal voltage plus 1000 volts.

257 *Exception*—**Auto-Starter Transformers or Starting Compensators,** used for starting purposes, shall be tested with the same voltage as the test voltage of the apparatus to which they are connected.

258 *Exception*—**Household Devices.** Apparatus taking not over †660 watts and intended solely for operation on supply circuits not exceeding 250 volts, shall be tested with 900 volts.

259 *Exception*—**Apparatus for use on Circuits of 25 Volts or Lower,** such as bell-ringing apparatus,* electrical apparatus used in automobiles, apparatus used on low-voltage battery circuits, etc., shall be tested with 500 volts.

260 *Exception*—**Field Windings of Alternating-Current Generators** shall be tested with 10 times the exciter voltage, but in no case with less than 1500 volts.

261 *Exception*—**Field Windings of Synchronous Machines,** including motors and converters requiring to be started from alternating-

*This rule does not include bell-ringing transformers of ratio 125 to 6 volts. See Code.
†The present code power limit for a single outlet.

current circuits, shall be tested with **5000** volts, when the field is wound for **125** volts, and with **8000** volts when the field is wound for **250** volts or over. In no case shall the test voltage be lower than that given in **§260**.)

262 *Exception*—**Phase-Wound Rotors of Induction Motors required to reverse in service.**

In order to allow for the extra voltage caused by the increased frequency at the instant of reversal, this test shall be four times stand-still voltage plus 1000.

263 *Exception*—**Switches and Circuit Control Apparatus** above **600** volts, shall be tested with 2¼ times rated voltage plus 2000. See **§367** to **387.**

264 *Exception*—**Assembled Apparatus.** Where a number of pieces of apparatus are assembled together and tested as an electrical unit, they shall be tested with 15 per cent lower voltage than the lowest required on any of the individual pieces of apparatus.

265 **Testing Transformers by Induced Voltage.** Under certain conditions it is permissible to test transformers by inducing the required voltage in their windings, in place of using a separate testing transformer. By required voltage is meant, a voltage such that the line end of the windings shall receive a test to ground equal to that required by the general rules.

266 **Transformers with Graded Insulation** shall be so marked. They shall be tested by inducing the required test-voltage in the transformer and connecting the successive line leads to ground.

MEASUREMENT OF VOLTAGE IN DIELECTRIC TESTS OF MACHINERY

267 **Use of Voltmeters and Spark-Gaps in Insulation Tests.** When making insulation tests on electrical machinery, every precaution must be taken against the occurrence of any spark-gap discharges in the circuits from which the machinery is being tested. A non-inductive resistance of about one ohm per volt shall be inserted in series with one terminal of the spark gap. If the test is made with one electrode grounded, this resistance shall be inserted directly in series with the non-grounded electrode. If neither terminal is grounded, one-half shall be inserted directly in series with each electrode. In any case this resistance shall be as near the measuring gap as possible and not in series with the tested apparatus. This resistance will damp high-frequency oscillations at the time of breakdown and limit the current which will flow. A water tube is the most reliable resistance. Carbon resistors should not be used because their resistance becomes very low at high voltages.

268 For Machinery of Low Capacitance. When the machinery under test does not require sufficient charging current to distort the high-voltage wave shape, or change the ratio of transfor-

mation, the spark gap should be set for the required test voltage and the testing apparatus adjusted to give a voltage at which this spark gap just breaks down. This adjustment should be made with the apparatus under test disconnected. The apparatus should then be connected, and with the spark gap about 20 per cent longer, the testing apparatus is again adjusted to give the voltage of the former breakdown, which is the assumed voltage of test. This voltage is to be maintained for the required interval.

269 For Machinery of High Capacitance. When the charging current of the machinery under test may appreciably distort the voltage wave or change the effective ratio of the testing transformer referred to in the first adjustment of voltage with the gap set for the test voltage should be made with the apparatus under test connected to the circuit and in parallel with the spark gap.

When making arc over tests of large insulators, leads, etc. partial arc-over of the tested apparatus may produce oscillations which will cause the measuring gap to discharge prematurely. The measured voltage will then appear too high. In such tests the "equivalent" ratio" of the testing transformer should be measured by gap to within 20% of the arc-over voltage of the tested apparatus with the tested apparatus in circuit. The measuring gap should then be greatly lengthened out and the voltage increased until the tested apparatus arcs over. This arc-over voltage should then be determined by multiplying the voltmeter reading by the equivalent ratio found above. Direct measurement of the spark-over voltage over one gap by another gap should always be avoided

270 **Measurements with Voltmeter.** In measuring the voltage with a voltmeter, the instrument should preferably derive its voltage from the high-tension circuit, either directly as with an electrostatic voltmeter; or through an auxiliary ***ratio transformer.*** It is permissible to measure the voltage at other places, such as the transformer primary, provided corrections can be made for the variations in ratio caused by the charging current of the machinery under test, or provided there is no material variation of this ratio. In any case, when the apparatus to be tested in sufficiently large in relation to the testing apparatus to cause wave distortion, the voltage must be checked by spark gap, as in **§275.**

A crest-voltage voltmeter has advantages over an r.m.s. voltage voltmeter, in determining the maximum cyclic value of the testing e.m.f; since it eliminates the necessity for determining the crest factor of the e.m.f. wave.

271 **Measurements with Spark Gaps.** If proper precautions are observed, spark gaps may be used to advantage in checking the calibration of voltmeters when set up for the purposes of high-pressure tests of the insulation of machinery.

272 **Ranges of Voltages.** For such Calibrating Purposes:

The Needle Spark-Gap should preferably be used for voltages from 10 kv. to 50 kv. because of the larger air gaps involved.

A Sphere Spark Gap should be used above 50 kv.

273 **The Needle Spark Gap.** The needle spark gap shall consist of new sewing needles supported axially at the ends of linear conductors which are at least twice the length of the gap. There must be a clear space around the gap for a radius of at least twice the gap length.

274 **Sparking Distance.** The sparking distances in air between needle points for various root-mean-square sinusoidal voltages in mm. are as follows:

NEEDLE-POINT SPARK-OVER VOLTAGES WITH NO. 00 SEWING NEEDLES

(At 25°C and 760 mm. barometer)

R.M.S. Kilovolts	Millimeters
10	11.9
15	18.4
20	25.4
25	33
30	41
35	51
40	62
45	75
50	90
60	118
70	149
80	180

The above values refer to a relative humidity of 80 per cent. Variations from this humidity may involve appreciable variations in the sparking distance.

275 **The Sphere Spark-Gap.** The standard sphere spark-gap shall consist of two suitably mounted metal spheres.

No extraneous body or external part of the circuit shall be near the gap within twice the diameter of the spheres.

The shanks should not be greater in diameter than 1/5th the sphere diameter. Metal collars, etc. through which the shanks extend, should be as small as practicable and should not during any measurement come closer to the sphere than the maximum gap length used in that measurement.

The sphere diameter should not vary more than 0.1 per cent and the curvature, measured by a spherometer, should not vary more than 1 per cent from that of a true sphere of the required diameter.

All gaps are affected by barometric pressure and temperature. and if tests are not made at 25°C and 760 millimeters barometer, appropriate corrections must be applied. The Institute is not at present prepared to make recommendations as to the amcunt of such correction.

The sparking distances between different spheres for various r.m.s. sinusoidal voltages will be assumed to be as follows:

276 **SPHERE GAP SPARK-OVER VOLTAGES**

(At 25°C and 760 mm. barometer)

Kilovolts	Sparking Distance in Millimeters.					
	125 mm. spheres		250 mm. spheres		500 mm. spheres	
	One Sphere Grounded	Both Spheres Insulated	One Sphere Grounded	Both Spheres Insulated	One Sphere Grounded	Both Spheres Insulated
40	19.1	19.1				
50	24.4	24.4				
60	30	30	29	29		
70	36	36	35	35		
80	42	42	41	41	41	41
90	49	49	46	45	46	45
100	56	55	52	51	52	51
120		71	64	63	63	62
140		88	78	77	74	73
160		110	92	90	85	83
180			109	106	97	95
200			128	123	108	106
220			150	141	120	117
240			177	160	133	130
260					148	144
280					163	158
300					177	171
320					194	187
340					214	204
360					234	221

The sphere gap is more sensitive than the needle gap to momentary rises of voltage and the voltage required to spark over the gap should be obtained by slowly closing the gap under constant voltage, or by slowly raising the voltage with a fixed setting of the gap.

INSULATION RESISTANCE OF MACHINERY

277 **The insulation resistance of a machine** at its operating temperature shall be not less than that given by the following formula:

Insulation Resistance in megohms =

$$\frac{\text{voltage at terminals}}{\text{rated capacity in kv-a.} + 1000}$$

The formula only applies to dry apparatus. Such high values are not attainable in oil-immersed apparatus.

Insulation resistance tests shall, if possible, be made at a d.c. pressure of 500 volts. Since the insulation resistance varies with the pressure, it is necessary that, if a pressure other than 500 volts is to be employed in any case, this other pressure shall be clearly specified.

The order of magnitude of the values obtained by this rule is shown in the following table:

Rated Voltage of machine	Megohms		
	100 kv-a.	1000 kv-a.	10,000 kv-a.
100	0.091	0.05	—
1,000	0.91	0.50	0.091
10,000	9.1	5.0	0.91
100,000	—	50	9.1

278 It should be noted that the insulation resistance of machinery is of doubtful significance by comparison with the dielectric strength. The insulation resistance is subject to wide variation with temperature, humidity and cleanliness of the parts. When the insulation resistance falls below that corresponding to the above rule, it can in most cases of good design, and where no defect exists, be brought up to the required standard by cleaning and drying out the machine. The insulation resistance test may therefore afford a useful indication as to whether the machine is in suitable condition for the application of the dielectric test.

REGULATION

DEFINITIONS

279 **Regulation.** The regulation of a machine in regard to some characteristic quantity (such as terminal voltage or speed) is the change in that quantity occurring between any two loads. Unless otherwise specified, the two loads considered shall be zero load and rated load and at the temperature attained under normal operation. The regulation may be expressed by stating the numerical values of the quantity at the two loads, or it may be expressed by the "percentage regulation" which is the percentage ratio of the change in the quantity occurring between the two loads to the value of the quantity at either one or the other load, taken as the normal value. It is assumed that all parts of the machine affecting the regulation maintain constant temperature between the two loads, and where the influence of temperature is of consequence, a reference temperature of 75°C shall be considered as standard. If change of temperature should occur during the tests the results shall be corrected to the reference temperature of 75°C.

The normal value may be either the no-load value, as the no-load speed of induction motors; or it may be the rated-load value as in the voltage of a.c. generators.

It is usual to state the regulation of d-c. generators by giving the numerical values of the voltage at no load and rated-load, and in some cases it is advisable to state regulation at intermediate loads.

280 The **Regulation of d-c. Generators** refers to changes in voltage corresponding to gradual changes in load and does not relate to the comparatively large momentary fluctuations in voltage that frequently accompany instantaneous changes in load.

In determining the regulation of a compound-wound d-c. gener-

ator, two tests shall be made, one bringing the voltage down and the other bringing the voltage up between no-load and rated load. These may differ somewhat, owing to residual magnetism. The mean of the two results shall be used.

281 In **constant-potential a-c. generators,** the regulation is the rise in voltage (when the specified load at specified power factor is thrown off) expressed in per cent of normal rated-load voltage.

282 In **constant-current machines,** the regulation is the ratio of the maximum difference of current from the rated-load value (occurring in the range from rated-load to short-circuit, or minimum limit of operation), to the rated-load current.

283 In **constant-speed direct-current motors,** and induction motors, the regulation is the ratio of the difference between full-load and no-load speeds to the no-load speed.

284 In **constant-potential transformers** the regulation is the difference between the no-load and rated-load values of the secondary terminal voltage at the specified power factor (with constant primary impressed terminal voltage) expressed in per cent of the rated-load secondary voltage, the primary voltage being adjusted to such a value that the apparatus delivers rated output at rated secondary voltage.

285 In **converters, dynamotors, motor-generators and frequency converters,** the regulation is the change in the terminal voltage of the output side between the two specified loads. This may be expressed by giving the numerical values or as the percentage ratio.

286 In **transmission lines, feeders etc.,** the regulation is the change in the voltage at the receiving end between rated non-inductive load and no load, with constant impressed voltage upon the sending end. The percentage regulation is the percentage change in voltage to the normal rated voltage at the receiving end.

287 In **steam engines, steam turbines and internal combustion engines,** the percentage speed regulation is usually expressed as the percentage ratio of the maximum variation of speed to the rated-load speed in passing slowly from rated load to no load (with constant conditions at the supply.)

288 If the test is made by passing suddenly from rated load to no load, the immediate percentage speed regulation so derived shall be termed the **fluctuation.**

289 In **a hydraulic turbine,** or other water motor, the percentage speed regulation is expressed as the percentage ratio of the maximum variation in speed in passing slowly from rated load to no load (at constant head of water), to the rated-load speed.

290 In **a generator unit** consisting of a generator combined with a prime mover, the speed or voltage regulation should be determined at constant conditions of the prime mover, *i.e.* constant steam-pressure, head, etc. It includes the inherent speed variations of the prime mover. For this reason, the regulation of a generator unit is to be distinguished from the regulation of either the prime mover, or of the generator combined with it, when taken separately.

CONDITIONS FOR TESTS OF REGULATION

291 **Speed and Frequency.** The regulation of generators is to be determined at constant speed, and of alternating-current apparatus at constant frequency.

292 **Power Factor.** In apparatus generating, transforming or transmitting alternating currents, the power factor of the load to which the regulation refers should be specified. Unless otherwise specified, it shall be understood as referring to non-inductive load, that is to a load in which the current is in phase with the *e.m f.* at the output side of the apparatus.

293 **Wave Form.** In the regulation of alternating-current machinery receiving electric power, a sine wave of voltage is assumed, except where expressly specified otherwise. See **§205.**

294 **Excitation.** In commutating machines, rectifying machines, and synchronous machines, such as direct-current generators and motors, as well as in alternating-current generators, the regulation is to be determined under the following conditions, so as to maintain the field adjustment constant at that which gives rated-load voltage at rated-load current.

(1) In the case of separately excited field magnets—constant excitation.

(2) In the case of shunt machines, constant resistance in the shunt-field circuit.

(3) In the case of series or compound machines, constant resistance shunting the series-field windings.

295 **Tests and Computation of Regulation of A-C. Generators.**

Any one of the three following methods may be used. They are given in the order of preference.

Method a.

The regulation can be measured directly by loading the generator at the specified load and power factor, then reducing the load to zero, and measuring the terminal voltage, with speed and excitation adjusted to the same values as before the change. This method is not generally applicable for shop tests, particularly on large generators, and it becomes necessary to determine the regulation from such other tests as can be readily made.

296 **Method b.**

This consists in computing the regulation from experimental data of the open-circuit saturation curve and the zero-power factor saturation curve. The latter curve, or one approximating very closely to it, can be obtained by running the generator with over-excited field on a load of idle-running under-excited synchronous motors. The power factor under these conditions is very low and the load saturation curve approximates very closely the zero power factor saturation curve. From this curve and the open circuit curve, points for the load saturation curve for any power factor can be obtained by means of vector diagrams.

To apply method b, it is necessary to obtain from test, the open-circuit saturation curve *OA*, Fig. 1, and the saturation curve *BC* at

zero power factor and rated-load current. At any given excitation *Oc*, the voltage that would be induced on open circuit is *ac*, the terminal voltage at zero power factor is *bc*, and the apparent internal drop is *ab*. The terminal voltage *dc* at any other power factor can then be found by drawing an e.m.f. diagram* as in Fig. 2, where ϕ is

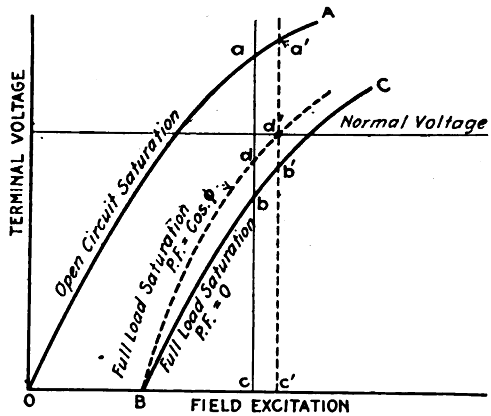


FIG. 1

an angle such that *cos* ϕ is the power factor of the load, *b e* the resistance drop (*IR*) in the stator winding, *ba* the total internal drop and *ac* the total induced voltage; *ba* and *ac* being laid off to correspond with the values obtained from Fig. 1. The terminal voltage at power

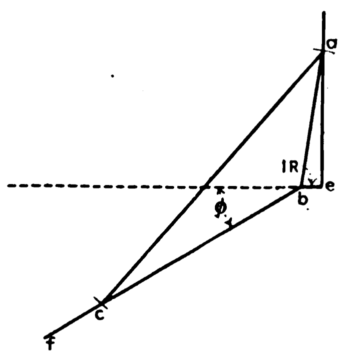


FIG. 2

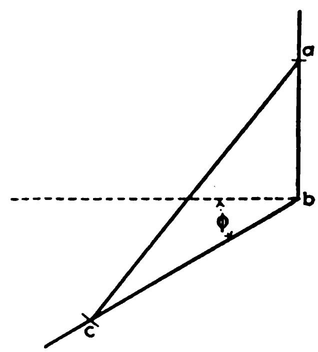


FIG. 3

factor *cos* ϕ is then *cb* of Fig. 2 which, laid off in Fig. 1, gives point *d*. By finding a number of such points, the curve *Bdd'* for power factor

*Method b, for deducing the load saturation curve, at any assigned power factor, from no-load and zero-power-factor saturation curves obtained by test, must be regarded as empirical. Its value depends upon the fact that experience has demonstrated the reasonable correctness of the results obtained by it.

cos ϕ is obtained and the regulation at this power factor (expressed in per cent) is $\frac{100 \times a'd'}{d'\,c'}$, since $a'\,d'$ is the rise in voltage when the load at power factor *cos* ϕ is thrown off at normal voltage $c'\,d'$.

Generally, the ohmic drop can be neglected, as it has very little influence on the regulation, except in very low-speed machines, where the armature resistance is relatively high, or in some cases where regulation at unity power factor is being estimated; for low power factors, its effect is negligible in practically all cases. If resistance is neglected, the simpler e.m.f. diagram, Fig. 3, may be used to obtain points on the load saturation curve for the power factor under consideration.

297 **Method c.**

Where it is not possible to obtain by test a zero power factor sat-

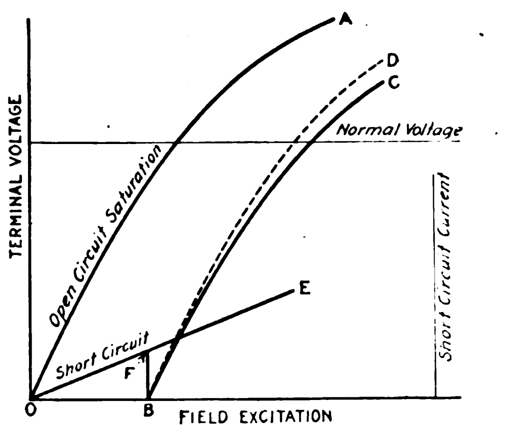


FIG. 4

uration curve as in (b), this curve can be estimated closely from open-circuit and short-circuit curves, by reference to tests at zero power factor on other machines of similar magnetic circuit. Having obtained the estimated zero power factor curve, the load saturation for any other power factor is obtained as in (b).

Thus Method (c) is the same as (b); except that the zero power factor curve must be estimated. This may be done as follows. In Fig. 4, OA is the open-circuit saturation curve and OE the short-circuit line as shown by test. The zero power factor curve corresponding to any given current BF will start from point B and for machines designed with low saturation and low reactance, will follow parallel to OA, as shown by the dotted curve BD, which is OA shifted parallel to itself by the distance OB. In high speed machines, or in others having low reactance and a low degree of saturation in the magnetic circuit, the zero power factor curve will lie quite close to BD, particularly

in those parts that are used for determining the regulation. This is the case with many turbo-generators or high-speed water-wheel generators. In many cases, however, the zero power factor curve will deviate from BD, as shown by BC, and the deviation will be most pronounced in machines of high reactance, high saturation, and large magnetic leakage. The position of the actual curve BC with relation to BD can be approximated with sufficient exactness by investigating the corresponding relation as obtained by test at zero power factor on machines of similar characteristics and magnetic circuit. Or curve BC can be calculated by methods based on the results of tests at zero power factor. After BC has been obtained, the saturation curve and regulation for any other power factor can be derived as in Method (b).

298 Tests and Computation of Regulation for Constant-Potential Transformers.

The regulation can be determined by loading the transformer and measuring the change in voltage with change in load at the specified power factor. This method is not generally applicable for shop tests, particularly on large transformers.

The regulation for any specified load and power factor can be computed from the percentage resistance drop and percentage reactance drop in the windings as follows:—

299 To compute the regulation of a constant-potential transformer, it is necessary to obtain the equivalent resistance R and impedance drop E_z. The equivalent resistance R of primary and secondary combined, is found by multiplying the secondary resistance by the square of the ratio of turns and adding it to the primary resistance. The impedance voltage E_z is found by short-circuiting the secondary winding and measuring the volts necessary to send rated-load current through the primary.

300 The reactance drop is then

$$IX = \sqrt{\left(E_z^2 - \frac{P}{I}^2\right)}$$

where P = impedance watts as measured in the short-circuit test. Let

E = rated primary voltage
IR = resistance drop in volts
IX = reactance drop in volts

$$q_r = 100 \frac{IR}{E} = \text{per cent resistance drop}$$

$$q_x = 100 \frac{IX}{E} = \text{per cent reactance drop}$$

301 Then—

1. For unity power factor

$$\text{Per cent regulation} = q_r + \frac{q_x{}^2}{200}$$

302 2. For inductive loads of power-factor m and reactive-factor n,

$$\text{Per cent regulation} = mq_r + nq_x + \frac{(mq_x - nq_r)^2}{200}$$

TRANSFORMER CONNECTIONS

SINGLE-PHASE TRANSFORMER

303 **Marking of Leads.**

The leads of single-phase transformers shall be distinguished from each other by marking the high-voltage leads with the letters A and B, and the low-voltage leads with the letters X and Y. They shall be so marked that the potential difference between A and B shall have the same direction at any instant as the potential difference between X and Y.

In accordance with the above rule, the terminals of single-phase transformers shall be marked as follows:

304 (1) High- and Low-Voltage Windings in Phase:

$$\begin{array}{c} A \text{———} B \\ X \text{———} Y \end{array}$$

305 (2) High- and Low-Voltage Windings 180 deg. Apart in Phase:

$$\begin{array}{c} A \text{———} B \\ Y \text{———} X \end{array}$$

306 To operate transformers thus marked in parallel, it is only necessary to connect similarly marked terminals together, (provided that the reactances and resistances of the transformers are such as to permit of parallel operation).

307 **Single-Phase Transformers with More Than Two Windings.**

Transformers possessing three or more windings (each being provided with separate out-going leads), shall have the leads connected to two of their windings, lettered in accordance with the preceding paragraph. The remaining leads shall be distinguished from the others by a subscript. For example, transformers possessing four secondary leads connected to two distinct similar windings for multiple-series operation, shall be lettered as follows:

$$\begin{array}{c} A \text{———} B \\ \left\{ \begin{array}{c} X \text{———} Y \\ X_1 \text{———} Y_1 \end{array} \right\} \end{array}$$

This indicates that the low-voltage winding consists of two disconnected parts, one part having terminals XY and the other part having terminals X_1Y_1. For multiple connection, X and X_1 are connected together and Y and Y_1 are connected together. For series connection, Y is connected to X_1.

308 **Neutral Lead**

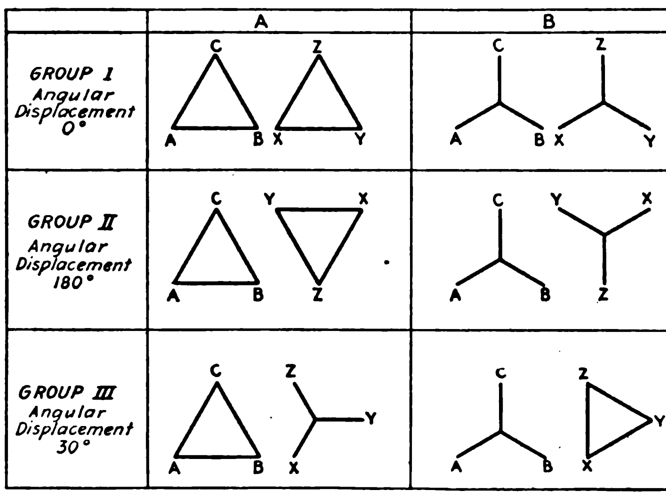
An out-going 50% (neutral) tap lead should be lettered N.

309 Internal Connections

The manufacturer shall furnish a complete diagrammatic sketch of internal connections, and all taps and terminals of the transformer shall be marked to correspond with numbers or letters in the sketch.

THREE-PHASE TRANSFORMERS

310 Three-phase transformers ordinarily have three or four leads for high-voltage, and three or four leads for low-voltage windings. To distinguish the various leads from each other, and also to distinguish between the various phase relations obtainable, the three high-voltage leads should be lettered A B C and the three low-voltage leads X Y Z. In addition, it should be distinctly stated in which of the three groups given in the accompanying diagram the transformer belongs.



The rules given above for single-phase transformers in regard to the neutral tap, and also in regard to internal connections, are applicable to three-phase transformers.

311 Angular Displacement.

The angular displacement between high- and low-voltage windings is the angle in the accompanying diagram, the lines passing from a neutral point through A and X respectively. Thus, in Group 1, the angular displacement is zero degrees. In Group 2, the angular displacement is 180°, and in Group 3 the angular displacement is 30°.

312 Parallel Operation of Three-Phase Transformers.

Three-phase transformers, lettered in accordance with the above rules, will operate correctly in parallel, if their percentage resistance drops are equal, and their percentage reactance drops, at their rated loads, are equal. It is furthermore necessary that the angular displacements between high-voltage and low-voltage windings shall

be equal, *i.e.* that the transformers shall belong to the same group in the accompanying diagram. It is then only necessary to connect together similarly marked leads.

INFORMATION TO BE GIVEN ON THE RATING PLATE OF A MACHINE*

313 (a) It is recommended that the rating plate of machines which comply with the Institute rules shall carry a distinctive special sign, such as "A.I.E.E. Rating."

(b) The absence of any statement to the contrary on the rating plate of a machine implies that it is intended for continuous service and for the standard ambient temperature of reference. See **§153** and **157.**

(c) The rating plate of a machine intended to work under various kinds of rating must carry the necessary information in regard to those kinds of ratings.

(d) The rating plate, in addition to the name of the manufacturer and the serial number, must give the following information. See also **§§391, 415.**

314 **Generator, Direct-Current.**

Shunt, series, or compound.
Output, in kw., with statement as to the kind of rating.
Terminal pressure, in volts.
Current, in amperes.
Speed, in revolutions per minute.

315 **Motor, Direct-Current,**

Shunt, series, or compound.
Output, in kw., with statement as to the kind of rating.
Terminal pressure, in volts.
Current, approximate, in amperes.
Speed, in revolutions per minute.

316 **Transformer.**

Frequency, in cycles per second.
Number of phases.
Output at the secondary terminals in kv-a., with statement as to the kind of rating.
Primary pressure, in volts.
Secondary pressure, in volts. See **§110.**
Lead markings and diagram of internal connections as stated in **§303** to **312.**

317 **Alternator.**

Frequency, in cycles per second.
Number of poles.
Number of phases.
Output, in kv-a., with statement as to the kind of rating power-factor corresponding to rated output.
Pressure between terminals, in volts, corresponding to the rated output.
Current in amperes.

---

*Information, for which space on the rating plate cannot be provided, shall be furnished on a subsidiary rating certificate.

Speed in revolutions per minute.
Excitation pressure, in volts.
Maximum exciting current, in amperes, required to maintain rated voltage under rated load.

318 **Synchronous Motor.**
Frequency, in cycles per second.
Number of poles.
Number of phases.
Mechanical output, in kw., with statement as to the kind of rating.
Pressure between terminals, in volts, corresponding to the rated output.
Current in amperes.
If the motor is intended to work with a power factor different from unity, the necessary information shall be given.
Speed, in revolutions per minute.
Excitation pressure, in volts.
Maximum exciting current, in amperes, required to maintain rated power factor under rated load.

319 **Synchronous Converter.**
Frequency in cycles per second.
Number of poles.
Shunt or compound.
Number of phases.
Output at commutator in kilowatts, with statement as to kind of rating. In case of a converter for railroad service, both nominal and continuous ratings.
A-c. terminal pressure in volts.
D-c. terminal pressure in volts.
Current from commutator in amperes.
Speed in revolutions per minute.

320 **Induction Motor.**
Frequency, in cycles per second.
Number of poles.
Number of phases.
Mechanical output, in kw., with statement as to the kind of rating
Pressure between terminals, in volts.
Current, in amperes.
Speed, in revolutions per minute, at rated output.
Secondary pressure (initial) when starting.

STANDARDS FOR WIRES AND CABLES

TERMINOLOGY*

321 **Wire.**—A slender rod or filament of drawn metal.

The definition restricts the term to what would ordinarily be understood by the term "solid wire." In the definition, the word "slender" is used in the sense, that the length is great in comparison with the diameter. If a wire is covered with insulation, it is properly called an insulated wire. While primarily the term "wire" refers to the metal, nevertheless when the context shows that the wire is insulated the term "wire" will be understood to include the insulation.

*From Circular No. 37 of the Bureau of Standards.

322 **Conductor.**—A wire or combination of wires not insulated from one another, suitable for carrying a single electric current.

The term "conductor" is not to include a combination of conductors insulated from one another, which would be suitable for carrying several different electric currents.

Rolled conductors (such as busbars) are, of course, conductors; but are not considered under terminology here given.

323 **Stranded Conductor.**—A conductor composed of a group of wires or any combination of groups of wires.

The wires in a stranded conductor are usually twisted or braided together.

324 **Cable.**—(1) A stranded conductor (single-conductor cable); or (2) a combination of conductors insulated from one another (multiple-conductor cable).

The component conductors of the second kind of cable may be either solid or stranded, and this kind of cable may or may not have a common insulating covering. The first kind of cable is a single conductor, while the second kind is a group of several conductors. The term "cable" is applied by some manufacturers to a solid wire heavily insulated and lead-covered. This usage arises from the manner of the insulation, but such a conductor is not included under this definition of "cable." The term "cable" is a general one and in practise it is usually applied only to the larger sizes. A small cable is called a "stranded wire" or a "cord," both of which are defined below. Cables may be bare or insulated, and the latter may be armored with lead or steel wires or bands.

325 **Strand.**—One of the wires or groups of wires of any stranded conductor.

326 **Stranded Wire.**—A group of small wires, used as a single wire.

A wire has been defined as a slender rod or filament of drawn metal. If such a filament is subdivided into several smaller filaments or strands and is used as a single wire, it is called a "stranded wire." There is no sharp dividing line of size between a "stranded wire" and a "cable." If used as a wire, for example in winding inductance coils or magnets, it is called a stranded wire and not a cable. If it is substantially insulated, it is called a "cord," defined below.

327 **Cord.**—A small cable, very flexible and substantially insulated to withstand wear.

There is no sharp dividing line in respect to size between a "cord" and a "cable," and likewise no sharp dividing line in respect to the character of insulation between a "cord" and a "stranded wire." Usually the insulation of a cord contains rubber.

328 **Concentric Strand.**—A strand composed of a central core surrounded by one or more layers of helically laid wires or groups of wires.

329 **Concentric-Lay Cable.**—A single-conductor cable composed of a central core surrounded by one or more layers of helically laid wires.

330 **Rope-Lay Cable.**—A single-conductor cable composed of a central core surrounded by one or more layers of helically laid groups of wires.

This kind of cable differs from the preceding in that the main strands are themselves stranded.

331 **N-Conductor Cable.**—A combination of N conductors insulated from one another.

It is not intended that the name as here given be actually used. One would instead speak of a "3-conductor cable," and a "12-conductor cable," etc. In referring to the general case, one may speak of a "multiple-conductor cable" (as in definition §324 above.)

332 **N-Conductor Concentric Cable.**—A cable composed of an insulated central conducting core with (N — 1) tubular stranded conductors laid over it concentrically and separated by layers of insulation.

Such constructions are usually only 2-conductor or 3-conductor. Such conductors are used in carrying alternating currents. The remark on the expression "N-conductor" given for the preceding definition applies here also.

333 **Duplex Cable.**—Two insulated single-conductor cables twisted together.

They may or may not have a common insulating covering.

334 **Twin Cable.**—Two insulated single-conductor cables laid parallel, having a common covering.

335 **Triplex Cable.**—Three insulated single-conductor cables twisted together.

They may or may not have a common insulating covering.

336 **Twisted Pair.**—Two small insulated conductors twisted together without a common covering.

The two conductors of a "twisted pair" are usually substantially insulated, so that the combination is a special case of a "cord."

337 **Twin Wire.**—Two small insulated conductors laid parallel, having a common covering.

338 **Specification of Sizes of Conductors.** The sizes of solid wires shall be stated by their diameter in mils, the American Wire Gage (Brown and Sharpe), sizes being taken as standard. The sizes of stranded conductors shall be stated by their cross-sectional area in circular mils. For brevity, in cases where the most careful specification is not required, the sizes of solid wires may be stated by the gage number in the American Wire Gage, and the sizes of stranded conductors smaller than 250,000 circular mils (*i.e.*, No. 0000 A.W.G. or smaller) may likewise be stated by means of the gage number in the American Wire Gage of a solid wire having the same cross-sectional area. Futhermore, an exception is made in the case of "Flexible Stranded Conductors," for which see **§341** below. In **stating large cross-sections,** it is sometimes convenient to use a circular inch (507 sq. mm.) instead of 1,000,000 circular mils.

STRANDING

339 The Standard Concentric Stranding Table printed in Circulars 31 and 37 of the Bureau of Standards, is adopted.

Standardization of Concentric Stranding.

Range of Sizes.		Number of Wires. Standard Concentric-lay Cables.
Circular mils.	Sq. mm.	
2,000,000 to 1,600,000....	1015 to 810	127
1,500,000 to 1,100,000....	760 to 560	91
1,000,000 to 550,000....	507 to 280	61
500,000 to 250,000....	253 to 127	37
No. 0000 to No. 1 A.W.G.	107 to 42	19
No. 2 and smaller.......	33	7

340 **Sectional Area of Cables.** The cross-sectional area of a cable shall be considered to be the sum of the cross-sectional areas of its component wires, when laid out straight and measured perpendicular to their axes.

341 **Flexible Stranding.** Conductors of special flexibility should ordinarily be made with wires of regular A.W.G. sizes, the number of wires and size being given. The approximate gage number or approximate circular mils of such flexible stranded conductors may be stated.

342 **Correction for Lay.** The resistance and mass of a stranded conductor are greater than in a solid conductor of the same cross-sectional area, depending on the lay (*i.e.*, the pitch of the twist of the wires). Two per cent shall be taken as the standard increment of resistance and of mass. In cases where the lay is definitely known, the increment should be calculated and not assumed.

The direction of lay is the lateral direction in which the strands of a cable run over the top of the cable as they recede from an observer looking along the axis of the cable.

343 **CONDUCTIVITY OF COPPER.**

The following I. E. C. rules are adopted:*

The following shall be taken as normal values for standard annealed copper:

(1) At a temperature of 20 deg. cent., the resistance of a wire of standard annealed copper one meter in length and of a uniform section of 1 square millimeter is 1/58 ohm = 0.017241.... ohm.

(2) At a temperature of 20 deg., cent. the density of standard annealed copper is 8.89 grams per cubic centimeter.

(3) At a temperature of 20 deg. cent., the "constant mass" temperature coefficient of resistance of standard annealed copper, measured between two potential points rigidly fixed to the wire, is 0.00393 = 1/254.45.... per degree centigrade.

(4) As a consequence, it follows from (1) and (2) that, at a temperature of 20 deg. cent. the resistance of a wire of standard annealed copper of uniform section, one meter in length and weighing one gram, is (1/58) × 8.89 = 0.15328...... ohm.†§

344 **Copper Wire Tables.** The copper-wire Tables published by the Bureau of Standards in Circular No. 31 are adopted. These Tables are based upon the I. E. C. rules stated in **§343.**

---

*See I. E. C. Publication No. 28 "International Standard of Resistance for Copper" March 1914.

†Paragraphs (1) and (4) of §343 define what are sometimes called "volume resistivity," and "mass-resistivity" respectively. This may be expressed in other units as follows:— volume resistivity = 1.17241 microhm-cm. (or microhms in a cm. cube) at 20 deg. cent. = 0.67879 microhm-inch at 20 deg. cent., and mass resistivity = 875.20 ohms (mile, pound) at 20 deg. cent.

§For detailed specifications of commercial copper, see the "Standard Specifications" of the American Society for Testing Materials.

HEATING AND TEMPERATURE OF CABLES.

345 **Maximum Safe Limiting Temperatures.**

The maximum safe limiting temperature in degrees cent. at the surface of the conductor in a cable shall be:—

For impregnated paper insulation	(85—E)
" varnished cambric	(75—E)
" rubber insulation	(60—0.25E)

where E represents the r.m.s. operating e.m.f. in kilovolts between conductors.

Thus, at a working pressure of 3.3 kv., the maximum safe limiting temperature at the surface of the conductor or conductors in a cable would be:—

For impregnated paper	81.7°C.
" varnished cambric	71.7°C.
" rubber	59.2°C.

ELECTRICAL TESTS.

346 **Lengths Tested.** Electrical tests of insulation on wires and cables shall be made on the entire lengths to be shipped.

347 **Immersion in Water.** Electrical tests of insulated conductors not enclosed in a lead sheath shall be made while immersed in water after an immersion of twelve (12) hours,if insulated with rubber compound, or if insulated with varnished cambric. It is not necessary to immerse in water insulated conductors enclosed in a lead sheath.

In multiple-conductor cables, without waterproof overall jacket of insulation, no immersion test should be made on finished cables, but only on the individual conductors before assembling.

348 **Dielectric-Strength Tests. Object of Tests.** Dielectric tests are intended to detect weak spots in the insulation and to determine whether the dielectric strength of the insulation is sufficient to enable it to withstand the voltage it is likely to be subjected to, in service, with a suitable factor of assurance.

The initially applied voltage must not be greater than the working voltage, and the rate of increase shall not be over 100 per cent in 10 seconds.

349 **Factor of Assurance.** The factor of assurance of wire or cable insulation shall be the ratio of the voltage at which it is tested to that at which it is used.

350 **Test Voltage.** The dielectric strength of wire and cable insulation shall be tested at the factory by applying an alternating test voltage between the conductor and sheath or water.

351 THE MAGNITUDE AND DURATION OF THE TEST VOLTAGE should depend upon the dielectric strength and thickness of the insulation, the length and diameter of the wire or cable, and the assurance factor required, the latter in turn depending upon the importance of the service in which the wire or cable is employed.

The following test voltages shall apply unless the departure is considered necessary in view of the above circumstances. Rubber covered wires or cable for voltages up to 7 KV shall be tested in accordance with the National Electric Code. Standardization for higher voltages for rubber insulated cables is not considered possible at the present time.

Varnish cambric and impregnated paper insulated wires or cables shall be tested at the place of manufacture for five (5) minutes in accordance with the table given below.

Different engineers specify different thickness of insulation for the same working voltages. Therefore at the present time the test KV corresponding to working KV given in the table below are based on the **minimum** thickness of insulation specified by engineers and operating companies.

RECOMMENDED TEST KILOVOLTS CORRESPONDING TO OPERATING KILOVOLTS

EMF Operating Kv.	EMF Test Kv.	
.5	2.5	The minimum thickness of insulation shall be 1/16″
2.5	3	
1	4	
2	6.5	
3	9	
4	11.5	
5	14	
10	25	
15	35	
20	44	
25	53	

352 The Frequency of the Test Voltage shall not exceed 100 cycles per second, and should approximate as closely as possible to a sine wave. The source of energy should be of ample capacity.

353 **Where Ultimate Break-Down Tests** are required, these shall be made on samples not more than 6 meters (20 ft.) long. The maximum allowable temperature at which the test is made for the particular type of insulation and the particular working pressure, shall not be greater than the temperature limits given in § **345**.

354 **Multiple-Conductor Cables.** Each conductor of a multiple conductor cable shall be tested against the other conductors connected together with the sheath or water.

INSULATION RESISTANCE

355 **Definition.** The insulation resistance of an insulated conductor is the electrical resistance offered by its insulation, to an impressed voltage tending to produce a leakage of current through the same.

The Standardization Committee does not commit itself to the principle of basing test voltages on working voltages, but it is not yet in possession of sufficient data to base them upon the dimensions and physical properties of the insulation.

356 Insulation resistance shall be expressed in megohms for a specified length (as for a kilometer, or a mile, or one thousand feet), and shall be corrected to a temperature of 15.5° C. using a temperature coefficient determined experimentally for the insulation under consideration.

357 Linear Insulation Resistance, or the insulation resistance of Unit Length, shall be expressed in terms of the megohm-kilometer, or the megohm-mile, or the megohm-thousand-feet.

358 **Megohms Constant.** The Megohms Constant of an insulated conductor shall be the factor " K " in the equation

$$R = K \log_{10} \frac{D}{d}$$

where R = The insulation resistance, in megohms, for a specified unit length.

D = Outside diameter of insulation.

d = Diameter of conductor.

Unless otherwise stated, K will be assumed to correspond to the mile unit of length.

359 **Test.** The apparent insulation resistance should be measured after the dielectric-strength test, measuring the leakage current after a one-minute electrification, with a continuous e.m.f. of from 100 to 500 volts, the conductor being maintained positive to the sheath or water.

360 **Multiple-Conductor Cables.** The insulation resistance of each conductor of a multiple-conductor cable shall be the insulation resistance measured from such conductor to all the other conductors in multiple with the sheath or water.

CAPACITANCE OR ELECTROSTATIC CAPACITY

361 **Capacitance** is ordinarily expressed in microfarads. Linear Capacitance, or Capacitance per unit length, shall be expressed in Microfarads per unit length (kilometer, or mile, or one thousand feet) and shall be corrected to a temperature of 15.5° C.

362 **Microfarads Constant.** The Microfarads Constant of an insulated conductor shall be the factor " K " in the equation

$$C = \frac{K}{\operatorname{Log}_{10} \frac{D}{d}}$$

where C = the capacitance in microfarads per unit length.

D = the outside diameter of insulation.

d = the diameter of conductor.

Unless otherwise stated, K will be assumed to refer to the mile unit of length.

363 **Measurement of Capacitance.** For Low-Voltage Cable. The Capacitance shall be measured by comparison with a standard condenser. For long lengths of high-voltage cables, where it is necessary to know the true capacitance, the measurement should be made at a frequency approximating the frequency of operation.

364 PAIRED CABLES. The capacitance shall be measured between conductors of pairs the other wires being connected to the sheath or ground.

365 ELECTRIC LIGHT AND POWER CABLES. The capacitance of low-voltage cables is generally of but little importance. The capacitance of high-voltage cables should be measured between the conductors and also, between each conductor and the other conductors connected to the lead sheath or ground.

366 **Multiple-Conductor Cables** (not paired). The capacitance of each conductor of a multiple conductor cable shall be the capacitance measured from such conductor to all of the other conductors in multiple with the sheath or the ground.

RATING AND TESTING OF SWITCHES AND OTHER CIRCUIT CONTROL APPARATUS

SWITCHES

367 The following rules apply to **Switches** of above 600 volts. (For 600 volts and below, see Code.*)

Definition. A device for making, breaking, or changing connections in an electric circuit.

368 **Rating.**

(a) By amperes to be carried with not more than 30 °C. rise on contacts and current-carrying parts.

(b) By normal voltage of circuit on which it may be used.

369 **Performance and Tests.**

(a) **Heating Test** with rated current applied continuously until temperature is constant; ambient temperature 40 °C.

(b) **Dielectric Test** at 2¼ times rated voltage plus 2000. See **§263.**

CIRCUIT BREAKERS

370 **Definition.** A device designed to open a current-carrying circuit without injury to itself. A circuit breaker† may be:

(a) An automatic circuit-breaker, which is designed to trip automatically under any predetermined condition of the circuit, such as an underload or overload of current or voltage.

(b) A manually tripped circuit-breaker, which is designed to be tripped by hand.

Both types of operation may be combined in one and the same device.

371 **Rating.**

(a) By normal current-carrying capacity.

(b) By normal voltage

(c) By amperes which it can interrupt at normal voltage of the circuit.

372 **Performance and Tests.** The heating test shall be made with normal current; in oil circuit breakers, same oil must be used for heating tests as for rupturing tests. Rise on contacts not to exceed 30 °C. Rise on tripping solenoids and accessory parts not to exceed 50 °C. Ambient temperature of reference, 40 °C.

373 **Dielectric Test.** Same as **§369.**

374 **Rupturing Test** must be made with the current specified under **§371** (c), and at normal voltage.

NOTE. Although circuit breakers should be considered as devices alone, no account being taken, in the rating, of the system on which they are to be used: yet in applying circuit breakers to any given service, it may be necessary to take into account the system on which they are to be used, with all its characteristics.

---

*By the term "Code" is meant "National Electrical Code" as recommended by the National Fire Protection Association.

†These rules refer only to circuit breakers of above 550 volts. For 550 volts and below, see Code.

Allowances must be made for the reactance, resistance, etc., of the circuit to be controlled, as these have a direct bearing on the maximum current flow.

In some systems it has been found that the pressure rises so high during switching, that higher insulation tests than that specified in **§369** should be given.

FUSES

(For circuits up to and including 600 volts, see Code)

375 **Definition.** An element designed to melt or dissipate at a a predetermined current value and intended to protect against abnormal conditions of current.

NOTE. (The terminals, tubes, etc. which go with the fuse proper are included in the definition).

376 **Rating.** Fuses shall be rated at the maximum current which they are required to carry continuously and at the normal voltage of the circuit on which they are designed to be used.

Fuses may be divided into two classes:

(1) Those designed to protect the circuit and apparatus both against short circuit and against definite amounts of overload (*e.g.* fuses of the code which open on 25 per cent overload).

(2) Those designed to protect the system only against short circuits; (*e.g.* expulsion fuses which blow at several times the current which they are designed to carry continuously). The line separating these two classes is not definitely fixed.

377 **Temperature.** Coils or windings (such as accompany fuses of the magnetic blowout type) should not exceed the limits set for machine coils having the same character of insulation. (See **§188** and **191**). The highest temperature for the fuse proper should not exceed the safe limit for the material employed (*e.g.* the temperature of the fibre tube of an enclosed fuse should not exceed the safe limit for this material, but an open-link metal fuse may be run at any temperature which will not injure the fuse material; except that no application of the above rule shall contravene the Code).

378 **Test.** For fuses intended for use on circuits of small capacity, or in protected positions on systems of large capacity, see Code. For large power fuses intended for service similar to that required of circuit breakers, see **§370** to **374**, or the Code as far as the latter applies.

LIGHTNING ARRESTERS

379 **Definition.** A device for protecting circuits and apparatus against lightning or other abnormal potential rises of short duration.

380 **Rating.** Arresters shall be rated by the voltage of circuit on which they are to be used.

Lightning arresters may be divided into two classes.

(a) Those intended to discharge for a very short time.

(b) Those intended to discharge for a period of several minutes.

NOTE. Complete standardization of these fuses above 600 volts according to the method of the Code is not advisable at this time, but is expected to be accomplished by an eventual extension of the Code. Until such extension is made, the following definitions and ratings may be followed.

381 **Performance and Tests.** Dielectric Test same as **§369.**

The resistance of the arrester at double potential and also at normal potential, determined by observing the discharge currents through the arrester.

(c) In the case of any arrester using a gap, a test shall be made of the spark potential on either direct-current or 60-cycle a-c. excitation.

(d) The equivalent sphere gap under disruptive discharge shall also be measured, using a considerable quantity of electricity.

(e) The endurance of the arrester shall be tested to continuous surges.

PROTECTIVE REACTANCES

382 **Definition.** A reactance for protecting circuits by limiting the current flow and localizing the disturbance under short-circuit conditions.

383 **Rating.**

(a) In kilovolt-amperes absorbed by normal current.

(b) By the normal current, frequency and line (delta) voltage for which the reactance is designed.

(c) By the current which the device is required to stand under short-circuit conditions.

384 **Performance and Tests.**

The Heat Test should be made with normal current and frequency applied until the temperature is constant. The temperature should not exceed the safe limits for the materials employed. See **§188** and **191.**

385 **Dielectric Test.** 2½ times line voltage plus 2000, for one minute, from conductor to ground.

NOTE. The reactance shall be so designed as to be capable of withstanding, without mechanical injury, rated current at normal frequency, suddenly applied.

RESISTOR OR RHEOSTAT

386 **Definition.** Any device commonly known as a resistance used for operation or control. See Code.

INSTRUMENT TRANSFORMERS

387 **Definition.** A transformer for use with measuring instruments, in which the conditions in the primary circuit as to current and pressure are represented with high numerical accuracy in the secondary circuit.

Under this heading and for more general use:

(a) A current transformer is a transformer designed for series connection in its primary circuit with the ratio of transformation appearing as a ratio of currents.

(b) A potential (voltage) transformer is a transformer designed for shunt or parallel connection in its primary circuit, with the ratio of transformation appearing as a ratio of potentials (voltages).

For further definitions relative to instrument transformers see **§111-114.**

STANDARDS FOR ELECTRIC RAILWAYS

DEFINITIONS

388 **Transmission System:** When the current generated for an electric railway is changed in kind or voltage, between the generator and the cars or locomotives, that portion of the conductor system carrying current of a kind or voltage substantially different from that received by the cars or locomotives, constitutes the ***transmission system.****

389 **Distribution System:** That portion of the conductor system of an electric railway which carries current of the kind and voltage received by the cars or locomotives, constitutes the ***distribution system.****

390 **Substation:** A substation is a group of apparatus or machinery which receives current from a transmission system, changes its kind or voltage, and delivers it to a distribution system.

RATING OF SUBSTATION MACHINERY

391 **Nominal Rating of Substation Machinery:** The nominal rating of a substation machine shall be the maximum output at 100 per cent power factor, which, having produced a constant temperature, may be increased 50 per cent for two hours without exceeding the standard ultimate temperature rise.

Substation machines shall be capable of carrying a load of twice their nominal rated load, for a period of five minutes, without disqualifying them for continued service. They shall also be capable of carrying a load of three times the nominal rated load for one minute. These overloads shall be applied after a continuous run at nominal rated load.

392 **Continuous Rating.** The continuous rating of a substation machine shall be that load, at 100 per cent power factor, which it will carry continuously with a temperature rise not exceeding that set forth in **§188**, and fulfilling the other requirements set forth in these Rules and summarized in **§132**.

CONDUCTOR AND RAIL SYSTEMS.

393 **Contact Conductors.** That part of the distribution system other than the traffic rails, which is in immediate electrical contact with the circuits of the cars or locomotives, constitutes the contact conductors.

394 **Contact Rail:** A rigid contact conductor.

395 OVERHEAD CONTACT RAIL: A contact rail above the elevation of the maximum equipment line.*

396 THIRD RAIL: A contact conductor placed at either side of the track, the contact surface of which is a few inches above the level of the top of the track rails.

*These definitions are identical in sense, although not in words, with those of the Interstate Commerce Commission, as given in their Classification of Accounts for Electric Railways.

397 CENTER CONTACT RAIL: A contact conductor placed between the track rails, having its contact surface above the ground level.

398 UNDERGROUND CONTACT RAIL: A contact conductor placed beneath the ground level.

399 GAGE OF THIRD RAIL: The distance, measured parallel to the plane of running rails, between the gage line of the nearer track rail and the inside gage line of the *contact surface* of the third rail.

400 ELEVATION OF THIRD RAIL: The elevation of the contact-surface of the third rail, with respect to the plane of the tops of running rails.

401 STANDARD GAGE OF THIRD RAILS: The gage of third rails shall be not less than 26 inches (66 cm.) and not more than 27 inches (68.6 cm.).

402 STANDARD ELEVATION OF THIRD RAILS: The elevation of third rails shall be not less than $2\frac{3}{4}$ inches (68.9 mm.) and not more than $3\frac{1}{2}$ inches (89 mm.).

403 THIRD RAIL PROTECTION: A guard for the purpose of preventing accidental contact with the third rail.

404 **Trolley Wire:** A flexible contact conductor, customarily supported above the cars.

405 **Messenger Wire or Cable:** A wire or cable running along with and supporting other wires, cables or contact conductors.

A primary messenger is directly attached to the supporting system. A secondary messenger is intermediate between a primary messenger and the wires, cables or contact conductors.

406 **Classes of Construction:** Overhead trolley construction will be classed as *Direct Suspension* and *Messenger or Catenary Suspension.*

407 DIRECT SUSPENSION: All forms of overhead trolley construction in which the trolley wires are attached, by insulating devices, directly to the main supporting system.

408 MESSENGER OR CATENARY SUSPENSION: All forms of overhead trolley construction in which the trolley wires are attached, by suitable devices, to one or more messenger cables, which in turn may be carried either in *Simple Catenary, i.e.,* by primary messengers, or in *Compound Catenary, i.e.,* by secondary messengers.

409 SUPPORTING SYSTEMS shall be classed as follows:

410 SIMPLE CROSS-SPAN SYSTEMS: Those systems having at each support a single flexible span across the track or tracks.

411 MESSENGER CROSS-SPAN SYSTEMS: Those systems having at each support two or more flexible spans across the track or tracks, the upper span carrying part or all of the vertical load of the lower span.

412 BRACKET SYSTEMS: Those systems having at each support an arm or similar rigid member supported at only one side of the track or tracks.

*The contour which embraces cross-sections of all rolling stock under all normal operating conditions.

413 BRIDGE SYSTEMS: Those systems having at each support a rigid member supported at both sides of the track or tracks.

414 STANDARD HEIGHT OF TROLLEY WIRE ON STREET AND INTERURBAN RAILWAYS: It is recommended that supporting structures shall be of such height that the lowest point of the trolley wire shall be at a height of 18 feet (5.5m.) above the top of rail under conditions of maximum sag, unless local conditions prevent. On trackage operating electric and steam road equipment and at crossings over steam roads, it is recommended that the trolley wire shall be not less than 21 feet (6.4m.) above the top of rail, under conditions of maximum sag.

RAILWAY MOTORS

RATING

415 **Nominal Rating**: The nominal rating of a railway motor shall be the mechanical output at the car or locomotive axle, measured in kilowatts, which causes a rise of temperature above the surrounding air, by thermometer, not exceeding 90 deg. cent. at the commutator, and 75 deg. cent.at any other normally accessible part after one hour's continuous run at its rated voltage (and frequency in the case of an alternating-current motor) on a stand with the motor covers arranged to secure maximum ventilation without external blower. The rise in temperature as measured by resistance, shall not exceed 100 deg. cent.*

416 The statement of the nominal rating shall also include the corresponding voltage and armature speed.

417 **Continuous Rating:** The continuous ratings of a railway motor shall be the inputs in amperes at which it may be operated continuously at $\frac{1}{2}$, $\frac{3}{4}$ and full voltage respectively, without exceeding the specified temperature rises (see §420), when operated on stand test with motor covers and cooling system, if any, arranged as in service. Inasmuch as the same motor may be operated under different conditions as regards ventilation, it will be necessary in each case to define the system of ventilation which is used. In case motors are cooled by external blowers, the volume of air on which the rating is based shall be given.

418 **Maximum Input.** Railway motors shall be capable of carrying twice the current corresponding to their nominal rating for a period

*This definition differs from that in the 1911 edition of the Rules, principally by the substitution of a kilowatt rating for the horse power rating and the omission of a reference to a room temperature of 25 deg. cent. The horse power rating of a railway motor may, for practical purposes, be taken as $\frac{4}{3}$ of the kilowatt rating. On account of the hitherto prevailing practise of expressing mechanical output in horse-power, it is recommended that, for the present, the capacity be expressed both in kilowatts and in horse-power, a double rating, namely,

kw.————————approx. equiv. h.p.————————

In order to lay stress upon the preferred future basis, it is desirable that on rating plates, the rating in kilowatts shall be shown in larger and more prominent characters than the capacity in horse power.

of five minutes, without flash-over or mechanical injury. They shall also be capable of carrying a load of three times their nominal rating for one minute under the same conditions. These overloads shall be applied when the motor is at the temperature which it would acquire when operating at its continuous rating.

TEMPERATURE LIMITATIONS

419 **The allowable temperature** in any part of a motor will be governed by the kind of material with which that part is insulated. In view of space limitations, and the cost of carrying dead weight on cars, it is considered good practise to operate railway motors for short periods at higher temperatures than would be advisable in stationary motors. The following temperatures are permissible:

Temperatures

Class of Material†	Maximum Observable Temperature of windings			
	Short Periods		Continuous	
	By Therm.	By Resist	By Therm	By Resist
A_2	100	125	85	110
B	115	145	100	130

420 With a view to not exceeding the above temperature limitations the continuous ratings shall be based upon the **temperature rises** tabulated below:

Temperature Rises on Stand Test*

Class of Material†	Temperature Rises of windings	
	By Thermometer	By Resistance
A_2	65	85
B	80	105

421 **Field-Control Motors.** The nominal and continuous ratings of field-control motors shall relate to their performance with the operating

*The temperature rise in service may be very different from that on stand test. See **§440** for relation between stand test and service temperatures, as affected by ventilation.

†See **§188.**

field which gives the maximum motor rating. Each section of the field windings shall be adequate to perform the service required of it, without exceeding the specified temperature rises.

CHARACTERISTIC CURVES

422 **The Characteristic Curves** of railway motors shall be plotted with the current as abscissas and the tractive effort, speed and efficiency as ordinates.

423 **Characteristic curves of direct-current motors** shall be based upon full voltage, which shall be taken as 600 volts, or a multiple thereof.

424 **In the case of field-control motors,** characteristic curves shall be given for all operating field connections.

EFFICIENCY AND LOSSES

425 **The efficiency** of railway motors shall be deduced from a determination of the losses enumerated in **§426, 427, 429** and **430.** (See also **§436** and **437.**)

426 **The copper loss** shall be determined from resistance measurements corrected to 75° C.

427 **The no-load core loss, brush friction, bearing friction and windage** shall be determined as a total under the following conditions:

In making the test, the kind of brushes and the brush pressure shall be the same as in commercial service. With the field separately excited, such a voltage shall be applied to the armature terminals as will give the same speed for any given field current as is obtained with the field current when operating at normal voltage under load. The sum of the losses above-mentioned, is equal to the product of the counter-electromotive force and the armature current. Under load, these losses shall be taken as follows:

Per Cent of Nominal Load	Loss as Per Cent of No-Load Losses
100 and over	130
75	120
50	115
25	110
15	100

428 In case it is desired to separate the **core loss** from the other losses above described, this may be accomplished by measuring the power required to drive the motor at any given speed without gears, by running it as a series motor on low voltage and deducting this loss from the sum of the no-load losses at corresponding speed. (See **§ 437**).

The core losses at other loads shall be assumed as follows:
At full continuous rated input 1.2 times no-load core loss.
" half " " " 1.1 " " " "
The multiplier for other loads shall be in the same proportion.

429 **The brush contact resistance loss** to be used in determining the efficiency, may be obtained by assuming that the sum of the drops at the contact surfaces of the positive and negative brushes is three volts.

430 The loss in single-reduction gearing and axle bearings varies with type, mechanical finish, age and lubrication. The following values, based on accumulated tests, shall be used in the comparison of motors:

Losses in Axle Bearings and Single-Reduction Gearings.

Per Cent of Nominal Rating	Losses as Per Cent of Input
100 or over	3.0
75	3.5
50	4.5
25	6.0

ELECTRIC LOCOMOTIVES

431 **Rating.** Locomotives shall be rated in terms of the adhesive weight, nominal one-hour tractive effort, continuous tractive effort and corresponding speeds.

432 **Adhesive Weight.** The adhesive weight expressed in pounds shall be the sum of the weights on the drivers and of the drivers themselves.

433 **Nominal Tractive Effort:** The nominal tractive effort, expressed in pounds, shall be that exerted when the motors are operating at their nominal (one-hour) rating.

434 **Continuous Tractive Effort.** The continuous tractive effort, expressed in pounds, shall be that exerted when the motors are operating at their full voltage continuous rating, as indicated in **§417.**

In the case of locomotives operating on intermittent service, the continuous tractive effort may be given for ½ or ¾ voltage, but in such cases the voltage shall be clearly specified.

435 **Speed:** The rated speed, expressed in miles per hour, shall be that at which the continuous tractive effort is exerted.

APPENDIX I.

RAILWAY MOTORS

436 In comparing projected motors and in case it is not possible or desirable to make tests to determine mechanical losses, the following values of these losses, determined from accumulated experience, will be found useful. They include axle-bearing losses, gear losses, armature bearing losses, brush-friction losses and windage.

Per cent of nominal rating	Losses as per cent of input
150 per cent	5.0
125 "	5.0
100 "	5.0
75 "	5.0
60 "	5.3
50 "	6.5
40 "	8.8
30 "	13.3
25 "	17.0

437 The core loss of railway motors is sometimes determined by separately exciting the field and driving the armature of the motor to be tested, by a separate motor having known losses and noting the differences in losses between driving the motor light at various speeds and driving it with various field excitations.

The core losses at other loads shall be assumed as follows:

At full continuous rated input 1.2 times no-load core loss,
" half " " " " 1.1 " " "

The multiplier for other loads shall be in the same proportion.

438 **Selection of Motor For Specified Service**

The following information relative to the service to be performed is required in order that an appropriate motor may be selected.

(a) Weight of total number of cars in train (in tons of 2000 lb.) exclusive of electrical equipment and load.
(b) Average weight of load and durations of same, and maximum weight of load and durations of same.
(c) Number of motor cars or locomotives in train, and number of trail cars in train.
(d) Diameter of driving wheels.
(e) Weight on driving wheels, exclusive of electrical equipment.
(f) Number of motors per motor car.
(g) Voltage at train with power on the motors—average, maximum and minimum.
(h) Rate of acceleration in m.p.h. per second.
(i) Rate of braking (retardation in m.p.h. per second).
(j) Speed limitations, if any (including slowdowns).
(k) Distances between stations.

(l) Duration of station stops.
(m) Schedule speed including station stops in m.p.h.
(n) Train resistance in pounds per ton of 2000 pounds at stated speeds.
(o) Moment of inertia of revolving parts, exclusive of electrical equipment.
(p) Profile and alignment of track.
(q) Distance coasted as a per cent of the distance between station stops.
(r) Time of layover at end of run, if any.

439 **Stand Test Method of Comparing Motor Capacity with Service Requirements:** When it is not convenient to test motors under actual specific service conditions, recourse may be had to the following method of determining temperature rise.

440 The essential motor losses affecting temperatures in service are those in the motor windings, core and commutator. The mean service conditions may be expressed as a close approximation, in terms of that continuous current and core loss which will produce the same losses and distribution of losses as the average in service.

A stand test with the current and voltage to which will give losses equal to those in service, will determine whether the motor has sufficient capacity to meet the service requirements. In service, the temperature of an enclosed motor (§ **97**), well exposed to the draught of air incident to a moving car or locomotive, will be from 75 to 90 per cent (depending upon the character of the service) of the temperature rise obtained on a stand test with the motor completely enclosed and with the same losses. With a ventilated motor (§ **98** and **100**), the temperature rise in service will be 90 to 100 per cent of the temperature rise obtained on a stand test with the same losses.

441 In making a stand test to determine the temperature rise in a specific service, it is essential in the case of a self-ventilated motor (§ **100**), to run the armature at a speed which corresponds to the schedule speed in service. In order to obtain this speed it may be necessary, while maintaining the same total armature losses, to change somewhat the ratio between the I^2R and core loss components.

442 **Calculation for Comparing Motor Capacity with Service Requirements.** The heating of a motor should be determined, wherever possible, by testing it in service, or with an equivalent duty cycle. When the service or equivalent duty cycle tests are not practicable, the ratings of the motor may be utilized as follows to determine its temperature rise.

443 The motor losses which affect the heating of the windings are as stated above, those in the windings and in the core. The former are proportional to the square of the current. The latter vary with the voltage and current, according to curves which can be supplied by the manufacturers. The procedure is therefore as follows:

444 (a) Plot a time-current curve and a time-voltage curve for the duty cycle which the motor is to perform, and calculate from these the root mean-square current and the equivalent voltage which with r.m.s. current will produce the average core loss.

445 (b) If the calculated r.m.s. service current exceeds the continuous rating, when run with average service core loss and speed, the motor is not sufficiently powerful for the duty cycle contemplated.

446 (c) If the calculated r.m.s. service current does not exceed the continuous rating, when run with average service core loss and speed, the motor is ordinarily suitable for the service. In some cases, however, it may not have sufficient thermal capacity to avoid excessive temperature rises during the periods of heavy load In such cases a further calculation is required, the first step of which is to calculate the temperature rise due to the r.m.s. service current, and equivalent voltage.

$$\left.\begin{array}{l}\text{Let } t = \text{temperature rise}\\ p_0 = I^2R \text{ loss, kW.}\\ p_c = \text{core loss, kW.}\end{array}\right\}\text{ with r.m.s. service current, and equivalent service voltage.}$$

$$\left.\begin{array}{l}T = \text{temperature rise}\\ P_0 = I^2R \text{ loss, kW.}\\ P_c = \text{core loss, kW.}\end{array}\right\}\text{ with continuous load current corresponding to the equivalent service voltage.}$$

Then

$$t = T\frac{p_0 + p_c}{P_0 + P_c}, \text{ approximately.}$$

447 (d) The thermal capacity of a motor is approximately measured by a coefficient equal to the ratio of the electrical loss in kW. at its nominal (one-hour) capacity,to the corresponding maximum observable temperature rise.

448 (e) Consider any period of peak load and determine the electrical losses in kilowatt-hours during that period from the *electrical* efficiency curve. Find the excess of the above losses over the losses with r.m.s. service current and equivalent voltage. The excess loss divided by the co-efficient of thermal capacity will equal the extra temperature rise due to the peak load. This temperature rise added to that due to the r.m.s. service current, and equivalent voltage, gives the total temperature rise. If the total temperature rise in any such period exceeds the safe limit, the motor is not sufficiently powerful for the service.

449 (f) If the temperature reached due to the peak loads does not exceed the safe limit, the motor may yet be unsuitable for the service, as the peak loads may cause excessive sparking and dangerous mechanical stresses. It is, therefore, necessary to compare the peak loads with the short-period overload capacity. If the peaks are also within the capacity of the motor, it may be considered suitable for the given duty cycle.

APPENDIX II.

*ILLUMINATION AND PHOTOMETRY.

460 **Luminous Flux** is radiant power evaluated according to its capacity to produce the sensation of light.

461 **The Luminous Intensity** of a point source of light is the solid angular density of the luminous flux emitted by the source in the direction considered; or it is the flux per unit solid angle from that source.

462 **Candle.** The unit of luminous intensity, maintained by the National Laboratories of France, Great Britain, and the United States. This unit, which is used also by many other countries, is frequently referred to as the international candle. The Hefner unit is 0.90 of the international candle.

463 **Candle-Power.** Luminous intensity expressed in candles.

464 **Lumen.** The unit of luminous flux, equal to the flux emitted in a unit solid angle (steradian) by a point source of one candle-power.

465 **Illumination** on a surface, is the luminous flux-density over that surface, or the flux per unit of intercepting area
Defining equation:
Let E be the illumination and S the area of the intercepting surface. Then

$$E = \frac{dF}{dS},$$

or, when uniform,

$$E = \frac{F}{S}$$

466 **Lux** a unit of illumination equal to one lumen per square meter. The C. G. S. unit of illumination is one lumen per square centimeter. For this unit Blondel has proposed the name " Phot." One milli-lumen per square centimeter (milliphot) is a practical derivative of the C. G. S. system. One foot-candle is one lumen per square foot and is equal to 1.0764 milliphots. The foot-candle is the commonly employed unit of illumination in English speaking countries.

467 **Exposure.** The product of an illumination by the time. Blondel has proposed the name " phot-second " for the unit of exposure in the C. G. S. system.

468 **Brightness, b, of an Element of a Luminous Surface from a Given Position** is the luminous intensity per unit area of the surface projected on a plane perpendicular to the line of sight, and including only a surface of dimensions negligibly small in comparison with the distance to the observer. It is measured in candles per

*Sections 460 to 496, on Illumination and Photometry have been taken from the Publications of the Illuminating Engineering Society, after conference with its Committee on Nomenclature and Standards. (See reports of that Committees).

square centimeter of the projected area.
Defining equation:
Let θ be the angle between the normal to the surface and the line of sight, and dI the luminous intensity of the element.
Then

$$b = \frac{dI}{dS \cos \theta}$$

469 **Normal Brightness,** b_0, **of an Element of a Surface** (sometimes called **Specific Luminous Intensity**) is the luminous intensity of the element taken normally to the surface of the element, and is expressed in candles per square centimeter.

In practice, the brightness b of a luminous surface, or element thereof, is observed, and not the normal brightness b_0. For surfaces for which the cosine law of emission holds, the quantities b and b_0 are equal.
Defining equation:

$$b_0 = \frac{dI}{dS}, \quad \text{or, when uniform,}$$

$$b_0 = \frac{I}{S}$$

470 **Specific Luminous Radiation.** The luminous flux-density emitted by a surface, or the flux emitted per unit of emmissive area. It is expressed in lumens per square centimeter.
Defining equation:
Let E' be the specific luminous radiation.
Then, for surfaces obeying Lambert's cosine law of emission:—

$$E' = \pi \, b_0$$

471 **Coefficient of Reflection.** The ratio of the total luminous flux reflected by a surface to the total luminous flux incident upon it. It is a simple numeric. The reflection from a surface may be regular, diffuse or mixed. In perfect regular reflection, all of the flux is reflected from the surface at an angle of reflection equal to the angle of incidence. In perfect diffuse reflection, the flux is reflected from the surface in all directions in accordance with Lambert's cosine law. In most practical cases, there is a superposition of regular and diffuse reflection.

472 **Coefficient of Regular Reflection** is the ratio of the luminous flux reflected regularly to the total incident flux.

473 **Coefficient of Diffuse Reflection** is the ratio of the luminous flux reflected diffusely to the total incident flux.
Defining equation:
Let m be the coefficient of reflection (regular or diffuse).
Then, for any given portion of the surface,

$$m = \frac{E'}{E}$$

474 **Primary Luminous Standard.** A recognized standard luminous source reproducible from specifications.

475 **Representative Luminous Standard.** A standard of luminous intensity adopted as the authoritative custodian of the accepted value of the unit.

476 **Reference Standard.** A standard calibrated in terms of the unit from either a primary or representative standard and used for the calibration of working standards.

477 **Working Standard.** Any standardized luminous source for daily use in photometry.

478 **Comparison Lamp.** A lamp of constant but not necessarily known candle-power against which a working standard and test lamps are successively compared in a photometer.

479 **Test Lamp,** in a photometer, a lamp to be tested.

480 **Performance Curve.** A curve representng the behavior of a lamp in any particular (candle-power, consumption, etc.) at different periods during its life.

481 **Characteristic Curve.** A curve expressing a relation between two variable properties of a luminous source, as candle power and volts, candle-power and rate of fuel consumption, etc.

482 **Mean Horizontal Candle-Power** of a lamp,—the average candle-power in the horizontal plane passing through the luminous center of the lamp.

It is here assumed that the lamp (or other light source) is mounted in the usual manner, or, as in the case of an incandescent lamp with its axis of symmetry vertical.

483 **Mean Spherical Candle-Power** of a lamp,—the average candle-power of a lamp in all directions in space. It is equal to the total luminous flux of the lamp in lumens divided by 4π.

484 **Mean Hemispherical Candle-Power of a Lamp** (upper or lower), —the average candle-power of a lamp in the hemisphere considered. It is equal to the total luminous flux emitted by the lamp in that hemisphere divided by 2π.

485 **Mean Zonal Candle-Power** of a lamp,—the average candle-power of a lamp over a given zone. It is equal to the total luminous flux emitted by the lamp in that zone divided by the solid angle of the zone.

486 **The Spherical Reduction-Factor** of a lamp

$$= \frac{\text{mean spherical candle-power}}{\text{mean horizontal candle-power}}$$

487 The **Spherical Reduction-Factor** should only be used when properly determined for the particular type and characteristics of each lamp. The spherical reduction-factor permits of substantially accurate comparisons being made between the total lumens, or mean spherical candle-powers of different types of incandescent lamps, and may be used in the absence of proper facilities for direct measurement of the total lumens or mean spherical candle-power.

488 **The Specific Output of Electric Lamps** is properly stated in terms of lumens per watt at lamp terminals. The use of the term efficiency in this connection should be discouraged.

When auxiliary devices are employed in circuit with a lamp, the specific output should be referred to lamp terminals, unless otherwise specified.

489 **The Specific Consumption** of an electric lamp is its watt consumption per lumen. "Watts per candle" is a term used commercially in connection with incandescent lamps, and denotes, watts per mean horizontal candle-power.

490 **Photometric Tests** in which the results are stated in candle-power should be made at such a distance from the source of light that the latter may be regarded as practically a point. Where tests are made in the measurement of lamps with reflectors, the results should always be given as "apparent candle-power" at the distance employed, which distance should always be specifically stated.

491 **Basis for Comparison.** Either the total flux of light in lumens, or the mean spherical candle-power, should always be used as the basis for comparing various luminous sources with each other, unless there is a clear understanding or statement to the contrary.

492 **Incandescent Lamps, Rating.** It is customary to rate incandescent lamps on the basis of their mean horizontal candle-power; but in comparing incandescent lamps in which the relative distribution of luminous intensity differs, the comparison should be based on their total flux of light measured in lumens, or on their mean spherical candle-power.

493 **Life Tests.** Similar filaments may be assumed to operate at the same temperature, only when their lumens per watt consumed are the same. Life tests are comparable only when conducted under similar conditions as to filament temperatures.

494 In **Comparing Different Luminous Sources** not only should their candle-power be compared, but also their relative form, brightness, distribution of illumination and character of light.

495 **Symbols.**

Photometric magnitude	Name of unit	Symbols
1. Luminous flux	Lumen	F, Ψ
2. Luminous intensity	Candle	I, Γ
3. Illumination	Phot., foot-candle, lux	E, β
4. Exposure	Phot-second	Et
5. Brightness	Apparent candles per sq. cm. Apparent candles per sq. in.	b
6. Normal brightness	Candles per sq. cm. Candles per sq. in.	b_0
7. Specific luminous radiation	Lumens per sq. cm. Lumens per sq. in.	E' β'
8. Coefficient of reflection.		m

496 In view of the fact that the symbols heretofore proposed conflict in some cases with symbols adopted for electric units by the International Electrotechnical Commission, it is pro-

posed that where the possibility of any confusion exists in the use of electric and photometric symbols, an alternative system of symbols for photometrical quantities should be employed. These should be derived exclusively from the Greek alphabet, for instance:

Luminous intensity.......................... Γ
Luminous flux.............................. Ψ
Illumination................................ β

STANDARDS IN TELEPHONY AND TELEGRAPHY

TENTATIVE DEFINITIONS*

501 After careful consideration it does not seem that the time is yet ripe for a formal standardization of terms and definitions used in telephony and telegraphy. Many of the terms commonly employed are used in more than a single way, and conversely, many pieces of apparatus and many constants which are essentially identical from a physical standpoint have been and are known by more than one designation.

502 **Damping of a Circuit.** The damping, at a given point, in a circuit from which the source of energy has been withdrawn, is the progressive diminution in the effective value of electromotive force and current at that point resulting from the withdrawal of electrical energy.

503 **Damping Constant.** The damping constant of a circuit is a measure of the ratio of the dissipative to the reactive component of its admittance or impedance.

Applied to the admittance of a condenser or other simple circuit having capacity reactance, the damping constant for a harmonic electromotive force of given frequency is the ratio of the conductance of the condenser or simple circuit at that frequency to twice the capacity of the condenser at the same frequency.

Applied to the reactance of a coil or other simple circuit having inductive reactance, the damping constant for a harmonic current of given frequency is the ratio of the resistance of the coil or circuit at that frequency to twice the inductance at the same frequency.

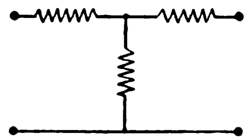
504 **Equivalent Circuit.** An equivalent circuit is a simple network of series and shunt impedances, which, at a given frequency, is the approximate electrical equivalent of a complex network at the same frequency and under steady state conditions.

NOTE: As ordinarily considered, the simple networks as defined, are the electrical equivalents of complex networks only with respect to definite pairs of terminals, and only as to sending-end impedances, and total attenuation. A further requirement is that the only connections between the pairs of terminals are those through the network itself.

*Comments or suggestions should be forwarded to the Chairman of the Sub-Committee on Telephone and Telegraph Standards.

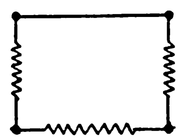
505 **"T" Equivalent Circuit.** A "T" equivalent circuit is a triple star or "Y" connection of three impedances externally equivalent to a complex network.

Symbol:



506 **"U" Equivalent Circuit.** A "U" equivalent circuit is a delta connection of three impedances externally equivalent to a complex network. It is also called a "Π" equivalent circuit.

Symbol:



IMPEDANCE

507 **Mutual Impedance.** The mutual impedance, for alternating currents, between a pair of terminals and a second pair of terminals of a net work, under any given condition, is the negative vector ratio of the electromotive force produced between either pair of terminals on open circuit to the current flowing between the other pair of terminals.

508 **Self Impedance.** The self impedance between a pair of terminals of a network, under any given condition, is the vector ratio of the electromotive force applied across the terminals to the current produced between them.

LINE CHARACTERISTICS

509 **Characteristic Impedance.** Characteristic impedance of a line is the ratio of the applied electromotive force to the resulting steady-state current upon line of infinite length and uniform structure, or of periodic recurrent structure.

NOTE: In telephone practice, the terms (1) line impedance, (2) surge impedance, (3) iterative impedance, (4) sending-end impedance, (5) initial sending-end impedance, (6) final sending-end impedance, (7) natural impedance and (8) free impedance, have apparently been more or less indefinitely and indiscriminately used as synonyms with what is here defined as "characteristic impedance."

510 **Sending-End Impedance.** The sending-end impedance of a line is the vector ratio of the applied electromotive force to the resulting steady-state current at the point where the electromotive force is applied.

NOTE: See note under "Characteristic Impedance." In case the line is of infinite length of uniform structure or of periodic recurrent structure, the sending-end impedance and the characteristic impedance are the same.

511 **Propagation Constant.** The propagation constant per unit length of a uniform line, or per section of a line of periodic recurrent structure, is the natural logarithm of the vector ratio of the steady-state currents at various points separated by unit length in a uniform line of infinite length, or at successive corresponding points in a line of recurrent structure of infinite length. The ratio is determined by dividing the value of the current at the point nearer the transmitting end by the value of the current at the point more remote.

512 **Attenuation Constant.** The attenuation constant is the real part of the propagation constant.

513 **Wave-Length Constant.** The wave-length constant is the imaginary part of the propagation constant.

LINE CIRCUITS

514 **Ground-Return Circuit.** A ground-return circuit is a circuit consisting of one or more metallic conductors in parallel, with the circuit completed through the earth.

515 **Metallic Circuit.** A metallic circuit is a circuit of which the earth forms no part.

516 **Two-Wire Circuit.** A two wire circuit is a metallic circuit formed by two paralleling conductors insulated from each other.

517 **Superposed Circuit.** A superposed circuit is an additional circuit obtained from a circuit normally required for another service, and in such a manner that the two services can be given simultaneously without mutual interference.

518 **Phantom Circuit.** A phantom circuit is a superposed circuit, each side of which consists of the two conductors of a two-wire circuit in parallel.

519 **Side Circuit.** A side circuit is a two-wire circuit forming one side of a phantom circuit.

520 **Non-Phantomed Circuit.** A non-phantomed circuit is a two-wire circuit, which is not arranged for use as the side of a phantom circuit.

521 **Simplexed Circuit.** A simplexed circuit is a two-wire telephone circuit, arranged for the super-position of a single ground-return signalling circuit operating over the wires in parallel.

NOTE: In view of the use of the term " Simplex Operation " in telegraph practise, it is felt that the designation " Simplexed Circuit " as applied to the arrangement described is not a happy one.

522 **Composited Circuit.** A composited circuit is a two-wire telephone circuit, arranged for the super-position on each of its component metallic conductors, of a single independent ground-return signalling circuit.

523 **Quadded or Phantomed Cable.** A quadded (or phantomed) cable is a cable adapted for the use of phantom circuits.

NOTE: The type of cable here defined has frequently been designated as " Duplex Cable "—a term which is objectionable,

both on account of its lack of description and its widely different use in telegraph practice.

LOADING

524 **Loaded Line.** A loaded line is one in which the normal inductance of the circuit has been altered for the purpose of increasing its transmission efficiency for one or more freqquencies.

525 **Series Loaded Line.** A series loaded line is one in which the normal inductance has been altered by inductance serially applied.

526 **Shunt Loaded Line.** A shunt loaded line is one in which the normal inductance of the circuit has been altered by inductance applied in shunt across the circuit.

527 **Continuous Loading.** A continuous loading is a series loading in which the added inductance is uniformly distributed along the conductors.

528 **Coil Loading.** A coil loading is one in which the normal inductance is altered by the insertion of lumped inductance in the circuit at intervals. This lumped inductance may be applied either in series or in shunt.

NOTE: As commonly understood, coil loading is a series loading, in which the lumped inductance is applied at uniformly spaced recurring intervals.

529 **Microphone.** A contact device designed to have its electrical resistance directly and materially altered by slight differences in mechanical pressure.

530 **Relay.** A relay is a device by means of which contacts in one circuit are operated under the control of electrical energy in the same or other circuits.

531 **Resonance.** Resonance of a harmonic alternating current of given frequency, in a simple series circuit, containing resistance, inductance and capacity, is the condition in which the positive reactance of the inductance is numerically equal to the negative reactance of the capacity. Under these conditions, the current flow in the circuit with a given electromotive force is a maximum.

532 **Retardation Coil.** A retardation coil is a reactor (reactance coil) used in a circuit for the purpose of selectively reacting on currents which vary at different rates.

NOTE: In telephone and telegraph usage the terms "impedance coil," "inductance coil," choke coil" and "reactance coil" are sometimes used in place of the term "retardation coil."

533 **Skin Effect.** Skin effect is the phenomenon of the non-uniform distribution of current throughout the cross-section of a linear conductor, occasioned by variations in the intensity of the magnetic field due to the current in the conductor.

534 **Telephone Receiver.** A telephone receiver is an electrically operated device designed to produce sound waves or vibrations which correspond in form to the electromagnetic waves or vibrations actuating it.

535 **Telephone Transmitter.** A telephone transmitter is a sound-wave or vibration-operated device designed to produce electromagnetic waves or vibrations which correspond in form to the sound waves or vibrations actuating it.

TRANSFORMERS

536 **The Coefficient of Coupling of a Transformer.** The coefficient of coupling of a transformer at a given frequency is the vector ratio of the mutual impedance between the primary and secondary of the transformer, to the square root of the product of the self-impedance of the primary and of the secondary.

537 **Repeating Coil.** A term used in telephone practice meaning the same as transformer, and ordinarily a transformer of unity ratio.

RADIO

538 **Acoustic Resonance Device.** One which utilizes in its operation mechanical or other resonance to the audio frequency of the received impulses.

539 **Antenna.** A system of conductors designed for radiating or absorbing the energy of electromagnetic waves.

540 **Atmospheric Absorption.** That portion of the total loss of radiated energy due to atmospheric conductivity.

541 **Audio Frequencies.** The normally audible frequencies lying between 20 and about 20,000 cycles per second. (See also Radio Frequencies.)

542 **Capacity Coupler.** An apparatus which electrostatically joins portions of two circuits, and thereby permits the transfer of electrical energy between these circuits through the action of electric forces.

543 **Coefficient of Coupling.** See **536** above.

544 **Conductive Coupler.** An apparatus which magnetically and electrically joins two circuits having a common conductive portion (also known as a Direct Coupler).

545 **Counterpoise.** A system of electrical conductors forming one plate of a condenser, the other plate of which is the ground. For alternating current, it may be used to replace a direct connection to ground.

546 **Damping of a Circuit.** See No. **502.**

547 **Damping Factor of a Simple Circuit.** The ratio of the effective resistance of that circuit to twice the effective inductance at any frequency. (The reciprocal of a time.) This term applies only to circuits capable of carrying free alternating currents. (See **503** above).

548 **Detector.** That portion of the receiving apparatus which, connected to a circuit carrying currents of radio-frequency, and in conjunction with a self-contained or separate indicator, translates the radio-frequency energy into a form suitable for operation of the indicator. This translation may be effected either by the conversion of the radio frequency energy, or by means of the control of local energy by the energy received.

549 **Electromagnetic Wave.** A progressive disturbance characterized by the existence on the wave front of electric and magnetic forces acting in directions which are perpendicular to each other and to the direction of propagation of the wave.

550 **Forced Alternating Current.** One produced in any circuit by the application of an alternating electromotive force.*

551 **Free Alternating Current.** That produced by an isolated electrical displacement in a circuit having capacity, inductance, and *less* than the critical resistance.†

552 **Critical Resistance of an Oscillating Current Circuit.** Twice the the square root of the ratio of the inductance of that circuit to the capacity of that circuit both expressed in practical units. This term applies only to circuits capable of carrying free alternating currents.

553 **Group Frequency.** The number of distinguishable alternating current groups occurring per second in an electrical circuit.

NOTE 1: The group referred to above is, in general mainly a free alternating current which is substantially damped to extinction before the beginning of the following group or train.

NOTE 2: The acoustic pitch of the note in the receiving station is, in general, determined by the group frequency at the transmitting station.

NOTE 3: The term "Group Frequency" replaces the term "Spark Frequency."

554 **Inductive Coupler.** An apparatus which magnetically joins portions of two electric circuits.

555 **Linear Decrement of a Circuit Containing a Resistance Element Equivalent to a Spark.** The difference of successive current amplitudes in the same direction divided by the larger of these amplitudes. (In circuits containing such an element, not the ratio of successive current amplitudes, but their difference is constant, and characteristic of the damping.)

556 **Logarithmic Decrement.** Logarithmic decrement of a circuit containing inductance, capacity, and constant resistance is one-half the ratio of the electrical energy withdrawn from that circuit during a cycle to the total energy present in that circuit at the beginning of the cycle. It also equals the natural logarithm of the ratio of successive current amplitudes in the *same* direction.

NOTE: Logarithmic decrements are standard for a complete period or cycle.

557 **Radio Frequencies.** Those above 20,000 cycles per second. (See also Audio Frequencies).

NOTE: It is not implied that radiation cannot be secured at lower frequencies and the distinction from audio frequencies is merely one of definition.

558 **Resonance to an Alternating Current.** See **531** above.

---

*In power applications termed simply an alternating current.

†In " " termed simply an oscillating current. See § 5.

559 **A Resonance Curve** gives the relation between circuit power, current, or voltage at various frequencies of excitation as a function of those frequencies.

560 **A Wave-Length Resonance Curve** is one wherein the abscissas are ratios of specified wave lengths to the resonant wave length, and the ordinates are ratios of the energy (or square of the current) at corresponding specified wave lengths to the energy (or square of the current) at the resonant wave length. The scale of ordinates and abscissas shall be equal.

561 **A Frequency Resonance Curve.** One wherein the abscissas are ratios of specified frequencies to the resonant frequency, and the ordinates are ratios of the energy (or square of the current) at corresponding specified frequencies to the energy (or square of the current) at the resonant frequency. The scales of ordinates and abscissas shall be equal.

562 **A Standard Resonance Curve** unless otherwise specified, is assumed to be a wave-length resonance curve.

563 **Selecting.** The process of adjusting an element driven by a plurality of simultaneous impulses, until the ratio of desired response to undesired response is a maximum.

564 **Sustained Radiation** consists of electromagnetic waves of constant amplitude (such as are emitted from an antenna in which flows a forced alternating current).

565 **Tuning.** The process of securing the maximum indications by adjusting the time period of a driven element. (In transmitter or receiver.)

566 **Wave-Length Meter.** A radio frequency measuring instrument calibrated to read wave lengths.

567 **Rating.** 1. All radio transmitting sets shall be rated in actual power output measured in the antenna.

Note: The group or audio frequency of the note of the station should be stated as well, (except for sustained wave sets, where that characteristic should be mentioned).

2. The over-all efficiency of a radio transmitting station shall be the ratio of the actual power output as measured in the antenna to the power input supplied to the first piece of electrical machinery which is definitely a part of the radio equipment.

Sections **538** to **567**, inclusive, have been inserted after conference with the Standards Committee of the Institute of Radio Engineers.

APPENDIX III.

BIBLIOGRAPHY OF LITERATURE RELATING TO ELECTRICAL ENGINEERING STANDARDIZATION

Engineering Manual of the American Electric Railway Engineering Association.

Standardization Rules of the Electric Power Club, 1913.

Report of the Committee on Standardization of the Institute of Radio Engineers, 1913.

National Electric Code.

Meter Code—Code for Electricity Meters of the A. E. I. C. and N. E. L. A. 1912.

Standardization Reports of the Association of Railway Electrical Engineers.

Publications of American Society for Testing Materials.

The U. S. Bureau of Standards various publications including Circulars 22, 23, 31, and 37.

Reports of Committee on Nomenclature and Standards of Illuminating Engineering Society.

National Electric Light Assocn.

FOREIGN PUBLICATIONS.

Publications of the International Electrotechnical Commission.

Publications of the Engineering Standards Committee of Great Britain.

Institution of Electrical Engineers, London, Wiring Rules and other publications.

Verband Deutscher Elektrotechniker.

British Electrical and Allied Manufacturers' Assocn., Standardization Rules.

INDEX.

D

E

K

L

M

Q

R

S

T

U

V

W

To be presented at the Pacific Coast Meeting of the American Institute of Electrical Engineers, Spokane, Wash., Sept. 9-11, 1914.

REPORT
by the
JOINT COMMITTEE ON INDUCTIVE INTERFERENCE
to the
RAILROAD COMMISSION OF THE STATE OF CALIFORNIA

LETTER OF TRANSMITTAL

San Francisco, July 7th, 1914.

To the Railroad Commission of the
State of California,
San Francisco, California.

Gentlemen:

The Joint Committee on Inductive Interference submits herewith a report based on its work to date, containing provisional rules which tend to improve conditions in respect to inductive interference. The investigation undertaken by the Committee has not been completed but the results already obtained serve to point out a number of requirements and precautionary measures which should be complied with in future work. These have been embodied in the rules presented herewith and *it is the recommendation of the Committee that these rules be made effective immediately without waiting for the completion of the investigation.*

The Committee desires to explain, in respect to certain of the rules, that while the general character of their essential provisions is well understood, the information available at present is not sufficiently complete to make it possible to set definite quantitative limits and to make all the rules explicit such as they should be in order to afford the maximum reduction of inductive interference consistent with the burden imposed by the rules. In a few instances, rules have been drawn with definite limits which have been set somewhat arbitrarily, in accordance with the Committee's best judgment. Therefore, the rules are not put forth as being complete or final but must be regarded as provisional and subject to such change as the results of further investigation and experience may determine. They are, however, recommended unanimously by the Committee as the best which can be formulated at this time and thus having the support of all the interests represented on the Committee, it is hoped that the rules will appeal to the Commission as being reasonable and proper.

The report also outlines other experimental work, some of which is now in progress, which the Committee considers essential in order that

additional information may be acquired for amplifying and revising these rules to make them more definite and complete.

Respectfully submitted,

RICHARD SACHSE
A. H. BABCOCK
R. W. GRAY
F. EMERSON HOAR
(Signed) J. E. WOODBRIDGE
J. P. JOLLYMAN
P. M. DOWNING
H. A. BARRE
C. H. TEMPLE
A. H. GRISWOLD
R. W. MASTICK
V. V. STEVENSON
J. A. KOONTZ
A. L. WILSON
Joint Committee on Inductive Interference.

Honorary Members:
HOWARD S. WARREN
JAMES T. SHAW

SCOPE

THIS report presents briefly an account of the formation of this Committee, its activities and results accomplished to date, and recommendations for such rulings by the Railroad Commission of the State of California as the Committee believes are justified at this time; together with a technical discussion in explanation of the results and recommendations.

HISTORICAL

The formation of the Joint Committee on Inductive Interference was the outgrowth of certain differences involving power, communication and railroad interests which were brought to the attention of the Railroad Commission of California. As an alternative to contesting the issue at that time it was agreed by the power and communication companies, with the approval of the Commission, that a joint investigation should be made to obtain certain information essential to a proper solution of the difficulties. The Commission desired that the matter be thoroughly investigated before passing upon the general principles involved in these difficulties. To this end a general conference was called to select representatives to form a "Joint Committee" empowered to conduct tests, experiments and investigations, the results of which would serve as a basis of recommendations for rules and regulations, to be issued by the

Commission, tending to minimize inductive interference and physical hazard arising from parallelism of different classes of circuits. This conference was held December 16, 1912. As a result, the Joint Committee on Inductive Interference, representing the Railroad Commission and railroad, power, and communication interests of the State, was organized and authorized by the Railroad Commission of California to conduct the desired investigation.

The organization and personnel of the Joint Committee on Inductive Interference were approved by the Railroad Commission on January 6, 1913, and the Committee thereupon proceeded with the necessary tests and investigations.

For the more efficient conduct of its work the Joint Committee was divided into several smaller sub-committees, each assigned to, and responsible for, certain branches of the investigation. The present organization of the Joint Committee is given on a chart presented as Appendix VI.

Early in its work the Joint Committee established a field engineering staff reporting to the Sub-committee on Tests, to conduct the necessary tests and investigations. This field staff was composed of engineers in the employ of The Pacific Telephone and Telegraph Company and the American Telephone and Telegraph Company and was later augmented by the addition of two engineers and a stenographer engaged by the Joint Committee.

Previous to the formation of this Committee in December 1912, The Pacific Telephone and Telegraph Company had started an investigation of inductive interference between the lines of the Coast Counties Gas and Electric Company and the lines of the telephone company in the neighborhood of Morganhill in Santa Clara County. This investigation was completed by the Joint Committee and its results have been considered in connection with other work carried out by the Joint Committee.

In January, 1913, the Joint Committee established its field staff at Salinas, to investigate parallels on the lines of the Sierra and San Francisco Power Company north of Salinas and on the lines of the Coast Valleys Gas and Electric Company south of Salinas, both of these power lines being parallel with lines of The Pacific Telephone and Telegraph Company, the Western Union Telegraph Company and the Southern Pacific Company's signaling system. The investigation at Salinas continued from January 1913 until July 1913.

The specific work undertaken at Salinas was: a determination of the magnitude and characteristics of the induction produced in the communication circuits, the factors in the power circuits causing this induction, the quantitative relationship of cause and effect, and a comparison of the effects on the parallels north of Salinas with the neutral of the power circuit alternatively grounded beyond one end of the parallel and beyond both ends of the parallel.

In July 1913 the field headquarters were moved to Santa Cruz. At this point the Committee desired to test the relative merits of various schemes of transposition for both power and telephone circuits, and to complete the investigation begun at Morganhill on the system of the Coast Counties Gas and Electric Company, which system is of a different character from that studied at Salinas. A mathematical study of transpositions in general, and particularly of those for the parallel between Santa Cruz and Watsonville, has been completed. The experimental study of these schemes of transpositions has not as yet been completed.

Owing to the peculiar nature of the experimental work and the refinements required, suitable apparatus was not easily obtainable and in many instances it was necessary to design and develop special apparatus for certain of the tests. A considerable amount of time has necessarily been spent at all points of the tests in choosing, from the almost innumerable things which could be investigated with profit, those of greatest value which could be carried out with the means at hand.

In the course of its investigations the Committee has prepared a series of fifty technical reports which present and discuss in detail the various features of the work, the methods and apparatus employed and the results accomplished. These reports, which are on file at the Committee headquarters in the offices of the Railroad Commission of California, are listed in Appendix V.

Results Accomplished

The following paragraphs summarize very briefly the principal results accomplished to date. These statements of results are accompanied by brief explanatory comment upon the conclusions reached. The reasons for and explanations of these conclusions are given in more detail in the appendices to which reference is made.

1. *Interference to telephone circuits under normal operating conditions of power circuits arises almost wholly from the harmonic voltages and currents of the power systems.* (*See Appendix I*).

This is due chiefly to the fact that the frequencies of the harmonics generally present in the voltages and currents of power systems cover a considerable portion of the range of the voice frequencies, particularly those frequencies at which telephone instruments and the human ear are of maximum sensibility. Extraneous currents of frequencies approaching the average voice frequency have a more injurious effect upon telephone conversation than currents of lower frequencies.

2. *The effect of induction of the fundamental frequency on telephone circuits is comparatively unimportant unless it is of magnitude sufficient to constitute a physical hazard.* (*See Appendix I*).

This is due to the fact that the fundamental approaches the lower limit of audible frequencies, at which the telephone and the human ear are not efficiently responsive.

3. *Interference to telegraph and other signaling circuits is due principally to the fundamental and lower harmonics.* (*See Appendix I*).

Telegraph receiving instruments are relatively insensitive, as compared with the telephone, to the higher harmonics, but are sensitive to disturbances of lower frequencies, such as the fundamental and lower harmonics which more nearly approach the normal operating frequency of such circuits.

4. *The power circuit currents and voltages may be divided into two factors: balanced and residual, of which, for equal magnitudes, the latter in general produce the greater inductive interference.* (*See Appendix II*).

Residual currents and voltages act inductively in a similar manner to single-phase currents and voltages acting in a circuit composed of the line conductors in parallel with earth return, which is a condition favorable to very large induction. Moreover, such a circuit which includes the earth as one side cannot be transposed. Transpositions in the power circuit cannot reduce the inductive effect of residuals except as they reduce the magnitudes of the residuals themselves, which they do in some cases. The inductive interference arising from such currents and voltages can be reduced only in the case of metallic circuits such as telephone circuits, by transposing these circuits. It is therefore important that the telephone circuits be trans-

posed at frequent intervals throughout parallels and carefully balanced throughout their entire length and that the residual currents and voltages be kept sufficiently small to give negligible induction in telephone circuits so arranged.

5. *Inductive interference to communication circuits, arising from the balanced voltages and currents, can in a large measure be prevented by means of an adequate system of transpositions applied to both power and communication circuits* (*assuming the latter are metallic*) *and located with due regard to each other.*

This is accomplished partly by creating mutually neutralizing inductive effects in neighboring lengths of each side of the communication circuit or circuits by transposing the power circuit, and partly by equalizing the inductive effects on the two sides of the communication circuit or circuits by exposing each side equally to the influence of the power circuit by transposing the communication circuit.

6. *Abnormal conditions and at times switching operations produce transient disturbances of a very severe character.*

This is due to the fact that abnormal conditions almost invariably give rise to residuals of large magnitude, often including high harmonics. Abnormal occurrences incident to electrical power transmission do not give warning of their occurrence, and since they cannot be produced artificially on transmission systems without subjecting the apparatus to great risk or danger, it has been deemed unwise to attempt any experimental tests of these effects. This conclusion is therefore drawn from general experience and data of actual occurrences collected by the Committee.

Rules Recommended by the Committee

The following are the rules which the Committee, as the result of its study to date, recommends be issued at this time to govern the future construction and operation of power and communication circuits which are or are proposed to be so located as to create a parallel as hereinafter defined.

Outline of Rules

Definitions.

a. Power Circuit
b. Communication Circuit
c. Telephone Circuit
d. Line.
e. Parallel or Parallelism

f. Residual Current
g. Residual Voltage
h. Transposition.

I. Avoidance of Parallelism

II. Conditions under which Parallelism will be Permitted.

a. Minimum Horizontal Separation
b. Balance of Power System
c. Limitation of Residual Currents and Voltages
d. Transpositions Inside Limits of Parallel
e. Transpositions Outside Limits of Parallel
f. Uniformity of Parallel
g. Transformer Connections
h. Switch Equipment
i. Switching
j. Use of Air Switches
k. Abnormal Conditions
l. Devices for Indicating Abnormal Conditions on Systems Isolated from Ground.
m. Procedure under Abnormal Conditions
n. Ammeters in Neutral Ground Connections
o. Charging Electrolytic Lightning Arresters
p. Wave Form of Rotating Machines
q. Exciting Current of Transformers.

III. Provisions Applying to Existing Parallels

IV. Waiver of Conditions by Communication Company

V. Parallelism with Alternating-Current Railways

Definitions

The following definitions are given of certain technical terms employed herein:

a. *Power Circuit.* The term "power circuit" includes any overhead constant-potential alternating-current power transmission or distribution circuit or electrically connected network which has a voltage of five thousand volts or more between any two conductors or of three thousand volts or more between any conductor and ground.

b. *Communication Circuit.* The term "communication circuit" includes any overhead, open wire telephone, telegraph, or signaling circuit which is used in the service of the public.

c. *Telephone Circuit.* The term "telephone circuit" includes any inter-exchange metallic telephone circuit, and therefore excludes subscriber's circuits. This term also includes any metallic telephone circuit operated by any railroad or other company for dispatching purposes or for public use between separate communities.

d. *Line.* The term "line" means any circuit or aggregation of circuits carried on poles or towers.

e. *Parallel or Parallelism.* The terms "parallel" or "parallelism" refer to cases where a power line and a communication line follow substantially the same course, or are otherwise in proximity for a sufficient distance, so that the power circuit is liable to create inductive interference in the communication circuits.

f. *Residual Current.* The term "residual current" denotes the vector sum of the currents in the several conductors of a power circuit.

g. *Residual Voltage.* The term "residual voltage" denotes the vector sum of the voltages to ground of the several conductors of a power circuit.

h. *Transposition.* The term "transposition" denotes the interchange of position of the several conductors of a circuit.

I. *Avoidance of Parallelism*

Every reasonable effort shall be made to avoid new parallelism. The party proposing to build a new communication or power line, which will create a parallel, or generally to reconstruct an existing line involved in a parallel shall give due notice (at least thirty days wherever possible) of its intention to the other party, including detailed information as to the location and character of the proposed line. If a plan can be devised and agreed upon by the two parties for maintaining an adequate separation between the two classes of lines so as to avoid interference, this shall be done. In case it is impracticable to secure adequate separation between a power line and a communication line, parallelism will be permitted subject to the conditions set forth in II.

II. *Conditions under which Parallelism will be Permitted*

a. *Minimum Horizontal Separation.* The minimum horizontal separation between the power line and communication line shall be equal to the height of the taller line. The only exceptions to this provision are angle crossings and other unavoidable cases of close proximity, and in all such cases the power line shall be kept above the communication line and constructed in conformity with the National Electric Light Association's specifications for overhead crossings or other approved equivalent which may be agreed to by both companies.

b. *Balance of Power System.* The power company shall exercise due diligence to keep the currents in, and the voltages to ground of, the conductors of any power circuit involved in a parallel, as closely balanced as practicable. In all cases where telephone circuits are involved, special consideration shall be given to the prevention or elimination of harmonics in the residual current and in the residual voltage.

c. *Limitation of Residual Currents and Voltages.* Pending additional rules on specific means other than those given herein, the parties concerned shall endeavor to agree upon the means to be employed for the prevention or limitation of residual currents and voltages, and in the event of disagreement the

matter shall be referred to the Railroad Commission of the State of California.

d. *Transpositions Inside Limits of Parallel.* An adequate system of transpositions shall be installed in the power circuit (or circuits), and in the communication circuit (or circuits) provided the latter is metallic. When both circuits are transposed the transpositions in both the communication and power circuits shall be located with due regard to each other.

Every reasonable effort shall be made by both parties concerned to fix the limits of the parallel and the location of crossings, branch lines, and connected apparatus so as to facilitate the application of an effective transposition scheme.

In the case of a parallel between a power line and a telephone line the company owning or operating the telephone line involved shall have the right to specify the number, type (in respect to electrical characteristics) and location of the transpositions in the power circuit subject to the following limitations:

1. For power circuits of 50,000 volts or over the average distance between successive transpositions shall not be required to be less than one mile and the minimum distance between any two successive transpositions shall not be required to be less than two-thirds of a mile.
2. For power circuits of less than 50,000 volts the distance between successive transpositions shall not be required to be less than one-sixth mile.

The transposition system of the telephone circuits shall be modified where necessary in order that the power and telephone circuits shall be, as nearly as practicable, mutually non-inductive.

For short parallels less than six miles in length (or short sections of longer parallels which have to be treated independently because of abrupt change in conditions) with power circuits of 50,000 volts or over, where it is impracticable to obtain an adequate balance by the location of transpositions in accordance with the limit specified above, the company owning or operating the telephone line involved shall have the right to specify the number, type and location of transpositions provided the distance specified between successive transpositions is not less than one-half mile.

When necessary (due to variations in lengths of telephone transposition sections) in order to secure an adequate balance, a reduction of 10 per cent in the limiting distances between successive power circuit transpositions as given above, shall be allowed.

In the case of a parallel between a power line and a tele-

graph line or other grounded communication circuit, the location of the transpositions in the power line shall be with due regard to the limits of the parallel in order to form as nearly as practicable a balanced system. The location and type of such transpositions shall be as specified by the communication company, subject to the condition that the transpositions in the power circuit may not be required to be less than one mile apart.

In no case shall the power company be required to relocate poles or towers for the transpositions.

The parties concerned in any proposed parallel shall endeavor to agree upon a transposition scheme for such parallel in accordance with the above. In the event of a disagreement, the matter shall be referred to the Railroad Commission of the State of California.

e. *Transpositions Outside Limits of Parallel.* In addition to transpositions within the limits of a parallel, as provided in "d" hereof, each new power circuit isolated from ground (or extension of such existing circuit) which is constructed subsequent to the date when these rules become effective, shall be transposed throughout its entire length in such manner as to balance the electrostatic capacities to earth of its several conductors, so as to avoid inequalities among the voltages to earth of the several conductors, which would create inductive interference. Such transpositions shall not be more than eight miles apart, provided however, that circuits less than three miles in length are not required to be transposed until they are extended to a greater length; except that extensions or spurs from existing lines, the electrostatic capacities to earth of whose conductors are balanced, shall be so constructed as not to change materially the balance of the existing lines to which they are connected.

f. *Uniformity of Parallel.* To facilitate the application of effective transpositions, both parties shall endeavor to maintain uniform separation, uniform arrangement of conductors and uniform relative location of the two classes of circuits within the limits of a parallel. However, when it is feasible to secure a substantial increase of separation between the two lines for a considerable portion of a parallel, this shall be done, as such an increase of separation is of more benefit than uniformity.

g. *Transformer Connections.* (1) On any power circuit involved in a parallel, no grounded single-phase, or grounded open-star transformer connections shall be employed.

NOTE: This does not apply to railroads operating alternating-current trolleys with ground return, which are covered by V.

(2) On a power circuit involved in a parallel, no star-connected transformers or auto-transformers with grounded neutral shall be employed, unless delta-connected secondary or tertiary windings or other equivalent means are used of suppressing the third harmonic components of the residual voltages and currents introduced by the transformers.

(3) Where single-phase loads are connected to a polyphase power circuit involved in a parallel, the power company shall endeavor to arrange successive connections of this type so as to equalize the loads upon the several phases.

(4) On a three-phase circuit involved in a parallel, the power company shall use, wherever practicable, a closed-delta connection in preference to an open-delta connection, and where the latter is employed an effort shall be made to distribute such connections equally upon the several phases.

h. *Switch Equipment.* A power circuit involved in a parallel shall be equipped, between the source of supply and the parallel, with oil switches, all poles of which shall be mechanically interconnected for simultaneous action. With the exception of stations where an operator is constantly on duty, these switches shall be rendered automatic for short-circuits, grounds, and abnormal neutral currents.

i. *Switching.* All switching on all parts of a system connected to a circuit involved in a parallel, which causes harmful transient disturbances in communication circuits, shall be done by means of oil switches, all poles of which are mechanically interconnected for simultaneous operation.

j. *Use of Air Switches.* The use of air switches, on a power circuit involved in a parallel, is prohibited except for purposes of isolating sections of dead line, or for disconnecting transformers under no load. This applies to the entire power system, any circuit of which is involved in a parallel, unless such switching is so remote as not to cause harmful transient disturbances in the communication circuits.

k. *Abnormal Condition.* A power circuit involved in a parallel shall not be operated at any time with an open, grounded or short-circuited line wire or wires or transformer winding.

l. *Devices for Indicating Abnormal Conditions on Systems Isolated from Ground.* If a power circuit involved in a parallel is electrically isolated from ground, reliable indicating devices

shall be installed at its source of supply to inform the operator immediately of abnormal conditions, such as grounds and wherever possible, open circuits, which have not operated automatic switches. Upon indication of trouble by such devices, the operator shall immediately open the oil switches and proceed in the manner outlined in "m".

m. *Procedure under Abnormal Conditions.* In case of the opening of an oil switch due to an abnormal condition in a power circuit involved in a parallel, or any circuit supplying or supplied by the same, such switch may be closed once; if opened a second time due to the continuance of the fault or abnormal condition, said switch shall not be closed again until the line has been sectionalized. The fault may then be located by energizing sections of line, provided that further sectionalization of the line be done in such sequence as to cause the minimum disturbance to parallel communication circuits, and provided further that where practicable the faulty section of line shall be energized but once in this process of sectionalization, where the fault exists within or beyond the parallel, until such fault is remedied.

n. *Ammeters in Neutral Ground Connections.* Wherever a neutral ground connection is employed on a circuit involved in a parallel, an ammeter, suitable for measuring as accurately as practicable the current in the neutral under normal operating conditions, shall be installed in all neutral connections at the main generating and substations on the power system electrically connected to the circuit involved in the parallel. The power company shall maintain a record of hourly measurements of the neutral current at all such points.

o. *Charging Electrolytic Lightning Arresters.* Where a power system is equipped with electrolytic lightning arresters so charged as to cause inductive interference in communication circuits the method of charging the arresters shall be modified to eliminate the disturbances as far as possible. The charging of such lightning arresters shall be done at such time as to give the minimum liability of interference with communication circuit operation, preferably between the hours of 2 A.M. and 4 A.M.

p. *Wave Form of Rotating Machines.* The power company shall make every effort to obtain generators and synchronous motors for use on all parts of the system, giving, as nearly as reasonably possible, pure sine waves of voltage at fundamental frequency. In no case shall the deviation from a pure sine

wave exceed the limit set forth in the Standardization Rules of the American Institute of Electrical Engineers.

q. *Exciting Current of Transformers.* In order that the wave shapes of voltage and current may be distorted as little as practicable by transformers, the main line transformers employed on circuits involved in a parallel and on future extensions of such circuits shall have an exciting current as low as is consistent with good practise, and in no case shall the exciting current at rated voltage exceed ten per cent of the full load current. Such transformers shall not be operated at more than ten per cent above their rated voltage.

III. Provisions Applying to Existing Parallels

The following sections of II shall apply also to power circuits involved in existing parallels; b, i, j, k, l, m, n, o, p, and q. Also g-3 and g-4 shall apply to existing parallels to the extent that transformers added hereafter shall be connected as provided in said rules.

IV. Waiver of Conditions by Communication Company

At the option of the company operating the communication circuit or circuits any of the provisions of II and III may be waived.

V. Parallelism with Alternating-Current Railways

It is recognized that railroads operating alternating-current trolleys with ground return create serious inductive interference with parallel communication circuits. In the present state of the art, no means for completely overcoming inductive interference from such parallels is known, hence, they are to be avoided if possible and where unavoidable, the responsibilities arising therefrom must be settled by mutual agreement or in case of inability to agree the matter shall be referred to the Railroad Commission of the State of California.

Discussion of Rules

It will be noted from the definitions that the terms "power circuit" and "telephone circuit" are used in these rules in a special, restricted sense.

(I) The first and most obvious means of preventing inductive interference is to avoid the close association of power and communication circuits. Further, it is recognized that in no other way can complete freedom from interference be secured. While with the ever increasing network of electrical circuits of all

kinds, adequate separation to avoid interference is becoming increasingly difficult to maintain, the Committee feels that the importance of such separation justifies its being made the first premise in rules designed to prevent inductive interference.

Notice, sufficiently in advance, should be given the other party or parties concerned in any proposed parallel in order that thorough consideration may be given by both parties to possible means of avoiding the parallel, or, in case the parallel cannot be avoided, to the necessary remedial measures to be employed.

(II-a) The best insurance against physical hazard in cases of close proximity is to maintain a separation equal to the height of the taller line, thus avoiding the possibility of physical contact in case of failure. In the case of crossings and unavoidable cases of close proximity for short distances extra-strength construction is necessary as a precaution against failure.

(II-b-c) As has been pointed out under the heading "Results Accomplished", and more fully explained in Appendix II, residual voltages and currents are particularly troublesome factors in causing interference. Means to eliminate or reduce such residuals in power systems are highly important and while information at this time does not enable the Committee to formulate as explicit a rule as is desirable, yet the importance of the subject justifies its inclusion in the rules. The acquisition of further information on which to base a more explicit rule upon this subject is a most important problem, the experimental study of which is discussed in the following section of this report.

(II-d) Transpositions properly located in both power and communication circuits offer the most reliable and effective means for preventing interference from balanced voltages and currents of power circuits. While the inductive effects increase in severity for the higher voltage circuits, due in part to the increased separation of the line conductors, which renders more frequent transpositions desirable, the mechanical difficulties involved are so great as to over balance the other reasons and the rules, therefore, provide for less frequent transpositions in the higher voltage circuits than in the lower voltage circuits. A further reason for frequent transpositions in the lower voltage circuits is the necessity of a flexible system of transpositions applicable to short parallels which generally occur with such circuits.

(II-e) The provision requiring transpositions outside the

limits of a parallel on systems electrically isolated from ground is an explicit measure for carrying out the purpose of the more general provision given under II-b-c, "Balance of Power System" and "Limitation of Residual Voltages and Currents."

(II-f) Non-uniformity of separation and type of construction within the limts of a parallel are inequalities which cannot in many cases be taken into account in the design and layout of transposition schemes. Such inequalities tend to nullify the effectiveness of the transpositions; hence, it is desirable that they be avoided. A precautionary statement is included in the rule in order that the possibility of securing a wide separation for a considerable portion of a parallel may not be sacrificed for the sake of absolute uniformity throughout the entire length.

(II-g) Some types of transformer connections and methods of operation give rise to large residual voltages and currents and certain provisions of the rules are designed to prohibit or restrict the use of such connections and methods of operation. These rules may be considered as explicit provisions complying with the general provision in II-b-c, "Balance of Power System" and "Limitation of Residual Voltages and Currents". The sufficiency of these specific provisions as an insurance against harmful residual voltages and currents is subject to future determination.

The present information of the Committee does not warrant the definite recommendation of any one type of connection or method of operation as best from the standpoint of inductive interference. This is true as to the relative merits of the two general types of systems, the grounded neutral and the isolated system. The advantages and disadvantages of these general types and any modifications of these types are dependent upon their inherent characteristics in respect to residuals and the limitations and control of residuals under both normal and abnormal conditions. Both types are on an equality with respect to the interference caused by balanced voltages and currents.

(II-k) Continued operation under certain abnormal conditions is possible in some power systems. In particular, it is possible to operate a grounded star-connected system with one phase open, and it is possible to continue the operation of an isolated system when one phase becomes grounded accidentally. The former gives rise to a large residual current and the latter to

a large residual voltage, both of which are liable to render parallel communication circuits inoperative. For these reasons the rule prohibits such operation, which, aside from the consideration of inductive interference, does not constitute good practise in power system operation.

(II-h-1-n) To provide that operation under the abnormal conditions mentioned above may not continue without the knowledge of the power company, the rules specify that devices for indicating grounds shall be installed on isolated systems. With respect to grounded star-connected systems, the rules specify with certain exceptions the automatic opening of switches by abnormal neutral currents. In such systems ammeters are required in all main neutral ground connections. Such ammeters, read regularly, afford means of detecting abnormal neutral currents and are of value in showing the degree of balance of the system, as the neutral current is easily affected by unbalanced conditions.

(II-m) Accidental causes give rise to occasional abnormal conditions. These can only be guarded against by good construction and maintenance, and careful operation which, however, cannot prevent entirely such occurrences. When trouble develops on a power circuit involved in a parallel, it is always liable to cause serious interference to the communication circuits, if the exposure is severe. In the present state of the art, the method of fault location on power circuits is a process of repeated sectionalization and energization of the faulty line until the fault is located within certain limits. This process causes repeated interruptions with loss of time in the operation of the communication circuits, and in the case of telephone circuits is accompanied sometimes by injury to the operators. It should be explained that the loss of time is much greater than the duration of the disturbance, owing to the time required to restore the protective devices on the communication circuits to their normal condition. No method of locating faults on power circuits is known which meets the requirements of practise and yet avoids the disadvantages of the present method. The inductive disturbances due to fault location can be to a considerable degree ameliorated by disconnecting the faulty line from the rest of the system and energizing this line by a single generator at such excitation as may be necessary to overcome the insulation of the fault. Whenever practicable this method is employed by power companies; hence, it has not been thought necessary to cover it by a specific rule.

In view of these facts, the Committee is recommending the limitation of the present practice in this regard so as to avoid, as far as seems practicable, the repeated interruptions to communication circuit operation. It is highly desirable that some better method of fault location be developed, not only because of the attendant consequences of the present method on communication circuits, but also because of the abnormal strains to which the power apparatus is necessarily subjected.

(II-h-i-j) Normal switching operations on power circuits produce at times severe transient disturbances in parallel communication circuits. The commonly recognized fact that oil switches produce less severe transient disturbances in power circuits, affords the basis for the provisions in the rules dealing with switches and switching. The automatic features required are designed to prevent continued operation under abnormal conditions.

(II-o) Transient disturbances of severe nature to telephone circuits are sometimes caused by the charging of electrolytic lightning arresters. There are available methods of diminishing the transients due to this cause, and a general provision to the effect that such methods shall be employed when necessary, is included in this rule. It is further provided that the charging of the arresters should be done at times when the telephone circuits are least used.

(II-p-q) Fundamentally, interference to telephone circuits by power circuits in normal operation is largely due to the existence of harmonics in the currents and voltages. While the complete elimination of these harmonics seems impracticable, still beneficial results may be obtained by practical efforts in this direction and the Committee feels that the two general provisions as to the wave form of rotating machines and the exciting current of transformers are of great importance both from a practical standpoint and also as enunciating a general principle. The matter of generator wave form particularly is of importance for all types of systems. The provision with reference to the exciting current of transformers, while desirable in all cases, is particularly so on grounded star-connected systems.

(III) Certain of the measures in II, particularly those referring to power system operation, which are helpful in mitigating inductive interference, have been recommended to apply to existing parallels.

(IV) Since these rules are designed for the protection of communication circuits, it is proper that the companies operating such circuits be given the right to waive any measures of protection which they may in any particular case consider unnecessary.

(V) The Committee has undertaken no investigation of cases of parallelism with alternating-current railways, but as the seriousness of this class of exposure is recognized, it was thought desirable that it be referred to specifically.

Future Work

The further work necessary in order to secure the information essential as a basis of determining more explicit and effective rules than those herein recommended, is particularly concerned with the subjects of transpositions and residual voltages and currents. In order to cover these subjects in as effective and economical a manner as possible it is thought that the procedure should be along the following lines:

1. Experimental study of transpositions, which includes the determination of:

a—the practical effectiveness of transpositions in both power and communication circuits as a means of reducing induction arising from balanced voltages and currents; involving considerations of different coordinated transposition schemes particularly with different lengths of power circuit "barrels."*

b—the practical effectiveness of transpositions in communication circuits as a means of reducing inductive interference arising from residual voltages and currents; involving considerations of different systems, particularly different lengths of balanced communication circuit transposition sections.

c—the influence of imperfect electrical balance of communication circuits in impairing the effectiveness of transpositions.

d—the practical effectiveness of transpositions in a power circuit isolated from ground as a means of balancing the electrostatic capacities to earth of the several conductors, and thereby reducing residual voltages and currents; involving considerations of the relative efficiency of different lengths of power circuit barrels.

2. Experimental study of the causes and effects of residuals, including:

a—a comparison of the different types of power system connection and apparatus in common use and their characteristics in respect to the production of residuals, particularly harmonic residuals.

b—means to be employed in limiting residual voltages and currents.

c—a determination of the minimum values of residual voltages and currents which will produce harmful inductive interference.

---

*See Appendix III, page 1345.

It is thought that these two studies could progress simultaneously. The work indicated under (1) could best be done on an actual parallel selected to be as uniform and as free from secondary disturbances as possible. Some preliminary work has been done along these lines which indicates the best methods of procedure and this should facilitate the carrying out of the investigation.

The study mentioned under (2) consists in part of an investigation of the characteristics and magnitude of residual voltages and currents in typical power systems, both those with grounded neutrals and systems entirely isolated from ground. A part of the study of residuals is logically related to the study of transpositions and could be carried out in connection with the study outlined under (1) and at the same time and place.

In addition to the above the Committee has already arranged for the investigation of the two following subjects:

1—a determination of the detrimental effect of extraneous currents on a telephone circuit as a function of the frequency, including a determination of the maximum amount of extraneous current, of different frequencies and combinations of frequencies, which is allowable in a commercial telephone circuit.

2—a determination of the effects of extraneous current of different amounts and characteristics, in limiting the speed of telegraph operation.

This work is now in progress.

APPENDIX I

Harmonics

Any complex electrical wave of periodic structure may be resolved into component sine waves of suitable amplitudes and phase differences, having frequencies which are in integral relation to the fundamental frequency. The simple sine wave of lowest frequency is termed the fundamental, and those of higher frequency are termed harmonics of the fundamental wave. The fundamental may be considered the first harmonic. The analysis of a periodic wave into its constituent sine waves or harmonics is not merely a mathematical conception or process but is in accordance with the facts of electricity and acoustics.

In general, alternating-current systems, by virtue of their inherent characteristics, do not permit the existence of harmonics other than odd integral multiples of the fundamental frequency, *i.e.*, 3rd, 5th, 7th, 9th, 11th, etc., harmonics. Such harmonics may exist in either or both the current and voltage waves of a power system.

Commercial frequencies of power transmission in California are 25, 50 and 60 cycles per second. The power systems, so far investigated, operate at a fundamental frequency of 60 cycles per second. The investigation has shown harmonic currents and voltages of appreciable magnitude up to the 35th harmonic. On one system the 23rd (corresponding to a frequency of 1380 cycles per second) has been found to be prominent. Induced currents and voltages in parallel communication circuits have been observed corresponding to these harmonics.

The detrimental effect of the induced voltages and currents in parallel communication circuits depends, in general, upon their magnitude and upon the frequency of the induction as compared with the operating frequency of the communication circuit. The presence of extraneous current of a frequency approaching that of normal operating frequency of the communication circuit has a more injurious effect than the same amount of current of a frequency far removed from the operating frequency of the circuit.

The frequency of the voice currents flowing in a telephone circuit ranges from about 200 cycles per second up to possibly 2000 cycles per second. The average voice frequency is considered to be approximately 800 cycles per second, and at about this frequency the telephone receiver is most sensitive. It is on account of these considerations that extraneous currents of the higher frequencies, arising from the harmonics of a power system, are relatively more detrimental to telephone service. The harmonics of the power systems have been found to be responsible for the greater portion of the inductive interference to telephone service, under normal operating conditions of parallel power circuits. Any extraneous current of a frequency within the audible range produces a disturbance which impairs the efficiency of a telephone circuit. The combined effects of all extraneous currents present, of frequencies within the range of audition, constitute the humming "noise" heard in the receiver of a telephone circuit which is subject to induction.

The effect of currents of the fundamental frequency (60 cycles or less) on telephone circuits is relatively unimportant as compared to that of higher harmonics, owing to the fact that the fundamental approaches the lower limit of audible frequencies. However, if the induction due to the fundamental becomes sufficiently great, constituting a physical hazard, or of such magnitude as to operate the protective devices on the

telephone circuits or interfere with superimposed telegraph service or other grounded signaling devices, it is then of great importance from the standpoint of interference.

In regard to the effect of extraneous currents on the operation of telegraph circuits, for reasons analogous to those given above, such circuits are relatively more affected by extraneous currents of fundamental frequency or of the frequencies corresponding to the lower harmonics such as the 3rd and 5th.

At the present time the American Telephone and Telegraph Company is undertaking, on behalf of the Joint Committee on Inductive Interference, an extensive series of tests in regard to the detrimental effect of extraneous currents of various frequencies on the intelligibility of telephone conversation. In addition, this company, in conjunction with the Western Union Telegraph Company and the Postal Telegraph Cable Company, is undertaking an investigation of the effect of extraneous currents on the operation of telegraph circuits and apparatus of different types.

Harmonic currents and voltages in power circuits arise from many causes. Generators or other rotating machines do not, in general, produce pure sine waves of fundamental frequency. This is due to several features in the design of the apparatus. A certain amount of distortion of wave form, with the consequent introduction of disturbing harmonics, is inherent with the use of transformers. This distortion of wave form is due to hysteretic action in the iron core of the transformer. The distortion varies in character and magnitude with the saturation and characteristics of the iron employed. Certain connections of transformers are possible which will suppress the third harmonic and its multiple in a three-phase power system. The fact that practically all inductive interference to telephone circuits is due to the harmonic currents and voltages, renders it important that an effort be made to obtain rotating machinery for use in power systems which produces as nearly as is reasonably possible pure sine waves of fundamental frequency, and also that an effort be made to obtain transformers and to arrange connections of the same in such a manner as to reduce as far as practicable the distortion of wave form.

APPENDIX II

Balanced and Residual Voltages and Currents

This appendix comprises the four following sections:

1. Analysis of Voltages and Currents and Discussion of the Effects of their Components.
2. Causes of Residual Voltages and Currents.
3. Means for Preventing or Reducing Residual Voltages and Currents.
4. Discussion of Tests.

1. *Analysis of Voltages and Currents and Discussion of the Effects of their Components*

To facilitate the analysis of inductive effects in parallel communication circuits, arising from a power circuit, the voltages and currents of the power circuits can be conveniently regarded as consisting of components which exhibit distinct characteristics and which may be treated separately.

Considering a three-phase circuit having equal voltages between any two conductors, the voltages to ground from the conductors can be resolved into two sets of components, balanced components and residual components. Since the voltages between any two conductors are equal, the voltages between the conductors may be graphically represented by three vectors forming an equilateral triangle. The potential of the ground may be represented by a point which may be inside or outside of the triangle, depending on the magnitude and character of the residual voltage, and the actual voltages to ground from the conductors may be represented by three vectors drawn between the point representing the ground potential and the corners of the triangle. The balanced components of the voltages to ground from the conductors consist of three equal voltages whose vector sum is zero and which are therefore displaced one-third cycle in time phase with respect to one another. These balanced components may be represented by three vectors drawn from the center of the equilateral triangle to the corners. The residual components of the voltages to ground from the conductors consist of three equal voltages which are in phase with one another and which may be represented by three identical vectors drawn from the point representing the ground potential to the center of the equilateral triangle. If the residual voltage is zero the point representing the ground potential will be at the center of the triangle. The residual voltage of the

system is defined as the vector sum of the voltages of the three conductors to ground. It is therefore, by definition, three times the residual voltage of the individual conductors, or three times the equivalent single-phase voltage of the three conductors in parallel with respect to the earth. It should be noted that the inductive effect of the residual voltage is equal to that of a single-phase voltage between ground and the three conductors in parallel equal to the residual voltage of the individual conductors or to one-third the residual voltage of the system.

If one conductor is grounded the residual components (assuming the voltages between wires remain unchanged) will each equal the voltage between conductors divided by the square root of three, and the residual voltage of the system will be equal to the voltage between conductors multiplied by the square root of three.

If a power circuit consists of a single conductor with ground return, the residual voltage will be equal to the voltage from the conductor to ground.

The currents flowing in the three wires of a three-phase, three-wire circuit can be considered to be composed of three sets of currents; namely, (1) balanced components consisting of equal currents in each of the three line wires whose vector sum is zero, and which are, therefore, displaced one-third cycle in time phase with respect to one another; (2) a single-phase current flowing in a loop composed of two of the line wires; (3) a residual current divided equally between the three line wires and returning through the earth. The residual current of the three-phase circuit is defined as the vector sum of the three line currents. It is, therefore, the equivalent of a single-phase current through the three line conductors in parallel, with the earth completing the circuit.

In the case of a power circuit consisting of a single conductor with a ground return the entire current flowing in the conductor is residual.

In the above discussion, reference is made to three-phase, three-wire power circuits, but the analysis there given may be generalized so as to apply to a power system of any number of phases. Most electrical power transmission systems are of the three-phase, three-wire type and subsequent statements will apply particularly to such systems, unless otherwise stated.

At a point in the vicinity of a power circuit, such as might represent the location of an element of a communication circuit

conductor, the resultant electromagnetic field due to the balanced currents would be zero if the power circuit conductors were equidistant from the point (disregarding the effect of the earth). In general, the power circuit conductors are not exactly equidistant from such point, and therefore the resultant electromagnetic field due to balanced currents is not zero. For this reason, the balanced currents in the power circuit have unequal effects on the communication circuit, hence there is a resultant induction. For residuals, there is, in general, a much greater inequality in the distances between the affected conductors (or circuits) and the sides of the residual circuit (power conductors in parallel one side, earth other side) than in the distances to the several power conductors, which constitute the circuit for the balanced components. Thus the resultant electromagnetic field due to residual currents is large in comparison with the field set up by balanced currents of the same magnitude. It may be noted that the electromagnetic forces at any point due to residual currents in the different power conductors are in the same time phase, hence the inductive effects of all the residual components are cumulative and not differential as in the case of the balanced components.

In a similar way it may be shown that residual voltages produce proportionately far greater inductive effects than balanced voltages.

Computations based on the physical characteristics of two of the parallels investigated show that, for an exposure near Salinas for eight miles with a 55,000-volt line on the opposite side of the county road from a communication line, one ampere of residual current produces as much induction in a ground return communication circuit as would forty amperes of balanced current; and one volt residual produces as much induction as one hundred and ten volts balanced. Similar computations based on the physical characteristics of an exposure between Santa Cruz and Watsonville, where the communication circuits are paralleled for seventeen miles by a 22,000-volt line on the opposite side of the county road, show that one ampere residual produces as much induction in a ground return communication circuit as would two hundred and forty amperes of balanced current; and one volt residual produces as much induction as twenty-five volts balanced. All of the above comparative values are for current and voltages of 60 cycles frequency.

The above values illustrate the relative induction-producing

powers of balanced and residual currents and voltages in two specific cases. Such values will vary considerably for different parallels, but these cited may be taken, in a general way, as indicative of the relative severity of the effects on a single conductor produced by these two factors. Such values for a unit length of non-transposed circuit in any given parallel, are dependent upon the separation, height, and configuration of the conductors of the two classes of circuits, and upon the character and condition of the ground and neighboring objects. For the entire parallel, or total length of exposure, these values are further dependent upon transpositions. The actual amount of induction arising from each of the two components depends also upon the actual magnitudes and the frequencies of the components in the power circuit.

It will be shown in Appendix III that inductive interference arising from balanced currents and voltages can be reduced by proper transpositions in the power circuit, but that power circuit transpositions do not reduce the inductive interference produced in a parallel communication circuit by residuals. Residual currents and voltages act inductively to produce the same effects as a single-phase grounded circuit operating with the three line conductors in parallel. This generally represents the worst possible condition from the standpoint of inductive interference. Transposing the conductors of the power circuit cannot reduce the inductive interference arising from residuals, except in so far as the magnitude of the residual voltages and currents is reduced by such transpositions. The effect of power circuit transpositions on the magnitude of these components is discussed below.

In the detailed discussion of transpositions in Appendix III it is shown that transpositions in a communication circuit can reduce the induced voltages from residuals only as between the two sides of a metallic circuit.

In view of the above it is evident that attention must be given to the problem of restricting residuals to amounts which do not cause material interference either to grounded communication circuits or to properly transposed and balanced metallic circuits.

2. *Causes of Residual Voltages and Currents*

While a degree of balance of the voltages and currents of the power system may be obtained which satisfies all the practical demands of power operation, this may not be sufficient to prevent the production of residuals sufficient to cause serious inductive interference to parallel communication circuits.

Residual currents and voltages may arise from one or more causes which act singly or together. The principal sources of residual currents and voltages are:

1. Unbalanced loads between the three phases and the neutral of a grounded star-connected system.
2. The introduction of the third harmonic and its odd multiples as residual current and voltage due to certain apparatus and connections employed on a grounded star-connected system.
3. Unbalanced capacity and leakage between the several phases of the system and ground. This applies more particularly to systems isolated from ground.

There are two principal types of commercial three-phase power circuits used in California:

1. The grounded neutral circuit or network in which all important generating points have a grounded neutral and in which all or part of the receiving points may be connected with a grounded neutral. No resistances are inserted between the neutrals and ground.
2. The isolated circuit or network which normally has no metallic connection to ground at any point.

The characteristics of the grounded neutral system with particular reference to residuals are as follows:

Under Normal Conditions.

(a) The impedances between line conductors and ground are determined very largely by the load impedances of the transformers. With balanced loads the residual voltage other than the third harmonic and its odd multiples may be eliminated.

(b) The effect of unbalanced loads on the residual voltage is small, as the tendency of generators and transformers is to maintain equal voltages between the several conductors and ground.

(c) With balanced loads the residual current, other than the third harmonic and its odd multiples, may be eliminated.

(d) Unbalanced loads between line and neutral cause corresponding residual currents, which will be large if the unbalance is large, as such unbalanced load currents flow through the neutral to earth.

(e) The varying permeability of the iron in star-connected transformers with grounded neutrals introduces the third harmonic and its odd multiples as residual voltages and currents. The use of delta-connected secondary windings reduces this effect greatly below that of star to star connections.

(f) Grounded star-connected generators connected directly to the line or through grounded star to star-connected banks of

transformers, may introduce the third harmonic and its odd multiples as residual voltages and currents.

Under Abnormal Conditions

(g) A ground on one phase short-circuits that phase through the neutral connection and causes a residual current throughout the whole length of the circuit, this current being practically equal to the short-circuit current to ground on that portion of the circuit between the sources of power supplying the fault and the point where the circuit is grounded. A large residual voltage (approaching as a maximum 58 per cent of the voltage between phases) will be created in proximity to the fault, and, if the low-tension side of the receiving transformers is star-connected, throughout that portion of the circuit between the fault and such receiving transformers. If the neutral of the receiving transformers is isolated, the short-circuit current will exist only between the source of supply and the fault and there will be no residual current between the fault and such receiving transformer. The above-mentioned residual voltage will in this case exist not only in proximity to the fault on the supply side but also throughout the length of circuit from the fault to the receiving transformers. The power circuit is rendered inoperative.

(h) An open condition of one phase causes a large residual current, as the unbalanced load currents of the other two phases must flow through the neutral to earth. A large residual voltage will exist beyond the fault if the low-tension side of the receiving transformers is star-connected. The power circuit may not be rendered inoperative for three-phase supply beyond the fault, in case the receiving transformers are grounded star-delta connected.

The characterisitics of the isolated system with particular reference to residuals are as follows:

Under Normal Conditions

(a) The impedances between line conductors and ground are determined by the electrostatic capacities and the leakage between the several conductors and ground. With balanced loads a residual voltage may exist due to unbalanced capacity and leakage. Such residual voltage as is due to unbalanced capacity may be eliminated by transposing the circuit so as to equalize the electrostatic capacities to ground of the several phases. If there are single-phase branches making the total lengths of the three conductors unequal, this will introduce

inequalities among the capacities to ground which it may not be possible to balance by transpositions. Inequalities in capacity or leakage result in unequal voltages between the different line conductors and ground.

(b) The effect of unbalanced loads on the residual voltage is very slight.

(c) With balanced loads a small residual current consisting of unbalanced charging current may flow, due to non-uniform distribution of unbalanced capacity and leakage.

(d) Unbalanced loads have but a slight effect upon the residual current.

(e) The transformers cannot introduce the third harmonic and its odd multiples as residual voltages or currents.

NOTE: Due to unsymmetrical three-phase connections sometimes employed (such as open-delta and Scott connections) the third harmonic and its odd multiples may appear in the voltages between lines and in the line currents, creating dissimilarities in the wave forms for the several phases. These harmonic components of the line voltages and currents are affected by unbalanced capacity and leakage in the same way as any other components as may appear in the residuals. It should be noted, however, that such harmonics are not impressed directly upon the line as residuals as is the case with grounded neutral systems.

(f) The generators cannot introduce the third harmonic and its odd multiples as residual voltages and currents.

NOTE: If a two-phase generator containing a third harmonic in its voltage wave supplies the line through Scott or other two- to three-phase transformer connections the third harmonic will appear in the voltage between lines. Subject to the conditions of the circuit as regards capacity and leakage balance, this harmonic along with all others may or may not appear in the residuals.

Under Abnormal Conditions

(g) A ground on one phase causes a large residual voltage (173 per cent of the voltage between phases) throughout the entire length of the circuit. A residual current will be created in proximity to the fault, its magnitude increasing with the extent, voltage and frequency of the system. The power circuit may not be rendered inoperative and the power company operators may be unaware of the existence of the abnormal condition. In some cases the residual voltage and current are greatly augmented by the resonant effects accompanying arcing grounds.

(h) An open condition of one phase may cause a large residual voltage, a certain amount of residual current will flow, due to the interchange of unbalanced charging current, between sections

of line on either side of the fault. The power circuit is rendered inoperative for three-phase supply beyond the fault.

A consideration of the characteristics of the two types of systems indicates that under normal operating conditions, with balanced loads upon all phases, the residuals of the grounded neutral system may be limited to the third harmonic and its odd multiples. The magnitude of these harmonics is dependent largely on the type of connection on the low-tension side of the transformer banks, the delta being preferable to star connection. Under the same condition the residuals of the isolated system may be limited to those resulting from unbalanced leakages to ground, which should be small on a well-maintained system. The effect of an unbalance in the loads connected between conductors upon the residuals of either type of system is small, while the effect of an unbalance in the loads connected between conductors and ground upon a grounded neutral system is to cause a residual current which is proportional to the amount of such unbalance, which will be large if the unbalance is severe. The residual current due to this cause, consists of the fundamental and all harmonics present in the line currents, in addition to which the third and its odd multiples are introduced as before by the varying permeability of the transformer iron, and in some cases by the generators.

Under abnormal conditions both types of systems give rise to residuals which are liable to cause interruption and damage to parallel communication circuits. The most frequent abnormal condition which produces severe interference is an accidental ground. A ground on one phase of a grounded star-connected system creates a severe and wide-spread electromagnetic unbalance, giving rise to corresponding inductive effects. This is accompanied by an electrostatic unbalance in the vicinity of such ground. On the lower voltage systems this latter effect is relatively of little importance. On the other hand, a ground on one phase of an isolated system creates a severe and wide-spread electromagnetic unbalance, giving rise to corresponding inductive effects. This is accompanied by an electromagnetic unbalance in the vicinity of the ground. On small low-voltage isolated systems, such electromagnetic unbalance is relatively of little consequence, but it should be noted that with increased voltage and extent of the system such effects do become of great importance, giving rise to electromagnetic disturbances in exposed communication circuits in addition to the electrostatic disturbances.

The magnitude of the inductive effects from either type of system is dependent upon the character of the exposure, extent of the power circuit and other factors which render it impossible with the information at hand to draw a definite conclusion as to the relative total amounts of interference inherent with the two types of system. Furthermore, it is not necessarily true that either type of connection has an advantage from the inductive interference standpoint for power systems of all sizes and voltages.

3. *Means for Preventing or Reducing Residual Voltages and Currents*

To minimize or prevent residual voltages and currents due to cause 1, it is necessary to equalize as closely as practicable at all points the load between the several phases of the circuit and the neutral, or to remove the ground path for unbalanced load currents, thus allowing a grounded neutral at one end of the circuit only. As it is difficult, if not impossible, to maintain all loads in a state of equilibrium at all times, the latter method has the advantage of greater reliability.

Single-phase connections to ground should not be employed. Where single-phase loads or unbalanced three-phase loads must be supplied, the transformers supplying such loads may be connected across the line wires, or may be connected star to delta, with the neutral not grounded. It should be noted that single-phase or unbalanced three-phase loads on the low-tension or delta side of grounded star to delta-connected transformers produce effects on the high-tension side similar qualitatively to single-phase loads between line and ground, but these effects are greatly reduced in magnitude by the inherent balancing influence of transformers so connected, due to the fact that all three transformers participate in supplying such a single-phase load.

Residuals which arise from cause 2 may be greatly reduced by means of certain types of connections for generators and transformers. Thus for example, connecting the secondary windings of the transformer banks in delta largely suppresses these components of the residual voltage and current but does not entirely prevent them. Where the transformers are connected grounded star to star, these components can be, to a certain extent, kept out of the line by the use of a second bank of transformers having a delta connection on one side and a star connection on the side in common with the first bank, with the neutrals interconnected.

The possibility of the introduction of third harmonic residuals

on the line due to the use of grounded star-connected generators may be avoided by the employment of transformers between generators and line, the windings on the generator side of the transformers being isolated from ground.

To eliminate or reduce residual currents and voltages which may be due to cause 3, it is necessary to transpose the conductors of the power circuit so as to equalize the electrostatic capacities of the several phases to ground, and this equalization must be attained within distances sufficiently short to prevent the accumulation of large unbalances. With a horizontal arrangement of conductors, the capacities to ground are more nearly equal that with the triangular or vertical arrangement. It is probable that the electrostatic capacities are the controlling factors in determining the residual voltage and current of an isolated system under normal operation, and while an investigation of the extent to which such residuals may be reduced by properly spaced transpositions has not yet been made, it is reasonable to suppose that transpositions will be substantially effective. The effect of unbalanced leakage cannot be controlled, except through proper construction and maintenance of the power system. It is to be noted that the maintenance of the system free from accidental grounds and partial grounds becomes increasingly difficult the larger the extent of the power network.

On a grounded star-connected system, the electrostatic capacity and the leakage of the several phases to ground are relatively less effective in producing residual voltage, as on such systems the voltages to ground are determined almost entirely by the generators and transformers.

4. *Discussion of Tests.*

Having given a general analysis of the causes and effects of and means to reduce residual currents and voltages, it is desirable to call attention to the results of tests which have been conducted, which have a bearing on this subject.

At Salinas, the effect of grounding or isolating the neutral of the auto-transformers, which have also a secondary delta winding, was investigated. These auto-transformers are supplied at 55,000 volts over a transmission line which parallels the circuits of The Pacific Telephone and Telegraph Company in what have been termed exposures No. 1 and No. 2. These auto-transformers in turn supply a 33,000-volt line of the Coast Valleys Gas and Electric Company, extending from Salinas to King City,

a distance of approximately 45 miles, and paralleling throughout practically this entire length, the coast route toll lead of The Pacific Telephone and Telegraph Company. These same telephone circuits are involved in the parallels with the 55,000-volt line north of Salinas. In addition to supplying the King City line this bank of auto-transformers at Salinas supplies a 22,000-volt line extending to Monterey, a distance of approximately 18 miles. Aside from the ground on the transformer neutral at Salinas, there are no grounds on either the 33,000-volt line or the 22,000-volt line. The 55,000-volt line supplying the Salinas transformers is energized at the Guadalupe substation of the Sierra and San Francisco Power Company, approximately 73 miles distant from Salinas, through grounded star-connected auto-transformers, which have delta-connected secondary windings, and which are supplied by the 104,000-volt line of this same system which operates with grounded neutral connection at its main generating station and substations. It will be understood from this statement of conditions that the neutral current at Salinas is not identical with the residual current of any one of the three high-tension lines which are connected together by these auto-transformers. The condition of the Salinas neutral affects the induction arising from the several exposures through its effect on the residual currents and voltages of the high-tension lines connected to the auto-transformers at that point. A representative value of the neutral current at Salinas during these tests is 0.3 ampere. It is composed almost entirely of the ninth harmonic, the fundamental and the third harmonic, their magnitudes decreasing in the order named. With the power system in normal operation, isolating the neutral of the auto-transformers at Salinas did not greatly affect the resultant induction in the particular exposures under observation. The values in the following table, taken from the data of the tests, indicate the effect of the condition of this neutral on the residual currents of the 55,000-volt and the 33,000-volt lines.

RESIDUAL CURRENT AT SALINAS—AMPERES.

Order of Harmonic	55,000-volt line.		33,000-volt line.	
	Neutral at Salinas		Neutral at Salinas	
	Grounded	Non-Grounded	Grounded	Non-Grounded
1	0.120	0.057	0.061	0.073
3	0.054	0.160	0.075	0.120
9	0.073	0.100	0.120	0.075

Two reasons may be given for the fact that the condition of the Salinas neutral does not greatly affect the resultant residual current of these lines: (1) the load balance on these lines is such that a relatively small amount of load current flows through this neutral: (2) as three high-tension lines are connected together by these auto-transformers, opening their neutral connection to ground does not completely eliminate the path for the residual current of any one of the three lines, since it may then flow to earth through the admittance to ground of the other two lines.

These particular conditions are not commonly found, but a similar condition, in that there is a path to ground for residual current aside from the neutral connection, prevails in any case where the power circuit extends for a considerable distance beyond such neutral connection. The investigation showed, for the conditions which applied to the 55,000-volt line, that removing the neutral ground connection beyond the parallel decreased the fundamental and increased the third and ninth harmonics in the residual current as shown in the above table. It is not be concluded, however, from this one case, that the third harmonic and its odd multiples in the residual current would in all cases be increased by removing the neutral ground connection of a bank of receiving transformers where the circuit extends beyond the point of measurement of such residual current. If the circuit is terminated at the transformer bank, the removal of the neutral ground connection must eliminate the residual current at that point.

In the case of the 33,000-volt line, the grounding of the neutral at Salinas merely gave another and nearer grounded neutral point on the line supplying power but did not give a grounded neutral point in each direction from the point of measurement of the residuals as it did in the case of the 55,000-volt line. As the 33,000-volt line has no grounded connection beyond Salinas, the residual current must flow to ground entirely through the admittance of this line to ground. The residual current, therefore, diminishes to zero at the King City end of the line. Isolating the neutral of the Salinas transformers affects the constituents of the residual currents in this line arising from the Salinas transformers, and those impressed by the 55,000-volt line, in such a way that they combine vectorially to give a different resultant from that with the Salinas neutral grounded. The result is to increase the fundamental and third harmonic and to decrease the ninth harmonic when the neutral is isolated. The residual current in the 22,000-volt

line was not determined but residual voltage measurements were made with the Salinas neutral isolated and grounded and the results are included in the following table, from which it may be noted that the fundamental, third and ninth harmonics were all greater with the Salinas neutral isolated.

The banks of star-connected auto-transformers at the Guadalupe and Salinas substations are provided with closed-delta secondary windings, which in the case of Salinas supply power for local consumption. An experimental opening of the delta at Salinas demonstrated, as would be anticipated, that the use of such delta-connected secondary windings reduces, in a large measure, the third harmonic introduced by these transformers in comparison with its value without the use of such delta-connected windings. If grounded star-connected transformers are used, it is important, therefore, from the standpoint of induction, to provide such transformers with closed-delta-connected secondary windings or with other means of reducing the third harmonic and its odd multiples. Such means may, however, in some cases be insufficient to reduce the residuals to such low values that they will not produce harmful inductive interference to parallel communication circuits.

The investigation on the system of the Coast Counties Gas and Electric Company shows results which are summarized in the following table with reference to the residual current and residual voltage. Santa Cruz, where the measurements were made, is 20 miles from one source of supply and 75 miles from the other end of the line where power was also supplied. For the sake of comparison the averages of the residual voltage of the 22,000-volt line between Salinas and Monterey, a distance of 18 miles, are also given:

Order of Harmonic	Residual Voltage—volts.			Residual Current amperes
		Salinas		
		Neutral		
	Santa Cruz	Grounded	Non-Grounded	Santa Cruz
1	360	50	90	0.094
3	—	150	320	—
9	19	40	50	0.021
11	14	—	—	0.017
13	10	—	—	—
23	14	—	—	—

The system of the Coast Counties Gas and Electric Company is isolated from ground and employs a number of Scott-connected and open-delta-connected transformers. The residuals at Santa Cruz on this system are composed principally of fundamental, ninth and eleventh harmonics. The fundamental is predominant. The third harmonic is absent or too small to measure accurately. It should be noted here that the use of Scott- and open-delta-connected transformers permits the third harmonic and its odd multiples to exist in the line voltages and currents of a three-phase isolated system. In all probability the residuals on this system are caused by unbalanced admittances to ground of the power line conductors. As has already been pointed out, that part of the unbalance due to electrostatic capacity could be greatly reduced by properly spaced transpositions in the power circuit. In contrast to the results at Salinas, the residuals of this system exhibit a prominent fundamental and the absence of, or relatively small amounts of, the third harmonic and its odd multiples.

APPENDIX III

Transpositions

The sources of the disturbances in communication circuits, which arise from parallel power circuits, have been treated in the first section of the preceding appendix. The effect of transpositions on the induction in communication circuits produced by parallel power circuits will now be considered.

This appendix comprises the four following sections:

1. Effect of Transpositions in Reducing Induction.
2. Characteristics of Present Transposition Systems.
3. Characteristics of Proposed Transposition Schemes.
4. Results of Tests.

1. *Effect of Transpositions in Reducing Induction.*

Transposing a circuit is the interchanging of the positions occupied by the conductors.

By transposing a power line the phase of the resultant electromagnetic field due to balanced currents and the phase of the resultant electrostatic field due to balanced voltages is changed, and the induction is reduced by the production of neutralizing effects in the neighboring lengths of a parallel conductor. Thus, by locating the power circuit transpositions so that each conductor occupies all of the several possible conductor positions

for equal distances, a section or "barrel" is obtained within which the resultant induction on a parallel conductor due to balanced currents and voltages is completely neutralized, neglecting attenuation and remanent electrostatic effect and assuming the parallel is uniform throughout the barrel.

Inasmuch as residual currents and voltages are in phase in the several conductors, the transposition of the power circuit does not reduce the inductive effects therefrom in a parallel conductor, except as the magnitudes of the residual currents and voltages are reduced by the power circuit transposition. (See Appendix II).

As usually constructed, the conductors of a telephone circuit are close together as compared with their distances to a power line, and the circuit is usually isolated from ground. Could the conductors of a metallic communication circuit be located at the same point in space, as is approximately true of a pair of wires twisted together, the resultant electromagnetic and electrostatic induction between the sides of the communication circuit would be zero. The voltage induced along the conductors of the telephone circuit and the induced voltage to ground would be present but would not be effective in producing any voltage between the conductors of the telephone circuit, provided the capacity and leakage to ground of each side of the telephone circuit were equal. On overhead lines the conductors of a metallic communication circuit must be at least several inches apart, hence in general when paralleled by a power line, the resultant electromagnetic and electrostatic induction in the two conductors will be unequal in magnitude. The result is that a voltage exists between the sides of the circuit which causes a current to flow in apparatus connected between the conductors, such as a telephone receiver.

Transpositions in communication circuits tend to equalize the induction in the two sides of the circuits by exposing each side equally to the influence of the power circuit, that is, by reversing in successive lengths the phase of the induction between the two sides of the circuit.

In an exposure where the induction from unbalanced currents and voltages would be completely neutralized by the power circuit transposition system if there were no communication circuit transpositions, or where such induction would be completely equalized by the communication circuit transpositions if there were no power circuit transpositions, this induction will practically

always be partially cumulative if both power and communication circuit transpositions are installed without due reference to each other. It should be noted, however, that the maximum disturbances which may be set up in a parallel communication circuit by balanced currents and voltages in the power circuit will be present when neither the power circuit nor the communication circuit is transposed. Hence it is very important that the power and communication circuit transpositions be properly located with respect to each other and in this way only can the maximum benefits from the transposition be derived.

Induction from residual currents and voltages is reduced by communication circuit transpositions.

If the communication circuit has a ground return, it cannot be transposed and the power circuit transpositions alone will be effective in reducing interference arising from the balanced currents and voltages. Also, the induction into a ground return communication circuit from residual currents and voltages is not affected by transpositions, except indirectly, as previously stated. It is possible, though not of general practical application, to obtain the effect of a transposition in a grounded alternating-current power or communication circuit by means of a transformer or repeating coil.

Induction between wires and ground is harmful to metallic as well as to ground return circuits, for in case the metallic circuit is not perfectly balanced electrically, such induced voltage forces a current to circulate in the metallic circuit through the terminal apparatus. It is not practical to maintain communication circuits in a state of perfect balance at all times.

2. *Characteristics of Present Transposition Systems.*

The transposition systems used on long distance metallic telephone circuits are designed primarily to reduce the "cross-talk" or induction from one telephone circuit into another and provide for a high degree of balance between any circuit and all others on the line.

The length of standard balanced telephone transposition sections used by The Pacific Telephone and Telegraph Company is approximately eight miles (more exactly, 41,600 feet), and this is representative of the length of sections of the transposition systems used by other companies operating similar lines. To improve the transmitting qualities of telephone circuits used for long distance work, loading coils are introduced in certain circuits at the ends of the standard transposition sections. Uniform

spacing of the telephone " S " poles (end poles of transposition sections) is an important consideration in the application of loading. It is important that the induction be neutralized in each section between loading points as these are points of discontinuity in the circuits.

The system now used also provides for the transposition of every circuit at actual intervals ranging from one-quarter mile to two miles, the average intervals for different circuits varying from approximately one-quarter mile to three-quarters of a mile, hence every circuit is to a certain extent balanced to induction from parallel power circuits.

In addition to the metallic circuits composed of two conductors, the telephone companies employ phantom circuits which are made up from two physical (two-wire) circuits. Each " conductor " or side of the phantom circuit consists of the two conductors which form one physical circuit. As usually made up, the physical circuits occupying adjacent horizontal positions are used for the phantom circuit. Hence, the average distance between the sides of the phantom circuit is equal to twice the distance between the conductors of the physical circuits. Due to the greater distance between the sides of the phantom circuit as compared with the physical circuits, the phantom circuits are more subject to inductive interference than the physical circuits. The phantom circuit possesses marked advantages in economy and transmission efficiency over the physical circuits composing it, hence, is extensively used for the longer distances. The transpositions in the phantom circuits are spaced at average intervals for different circuits, varying approximately from three-quarters of a mile to two miles.

The purpose of transposition systems applied to power circuits has been to reduce the disturbance in parallel communication circuits and in some cases to equalize the separation of the pairs of conductors forming the several phases. Usually when transpositions have been applied to power circuits to reduce the disturbance in existing parallel communication circuits, one or more complete barrels have been provided within the total length of the exposure. The best obtainable results from power circuit transpositions will be had only when they are located with due regard to the transposition points of the communication circuit. No such practise as this has been followed in the past. The transposition systems heretofore applied to parallel power and communication circuits have therefore failed to meet

the requirements for maximum effectiveness. Hence, balanced currents and voltages in the power circuits have, in general, caused more disturbance than necessary in parallel communication circuits.

3. *Characteristics of Proposed Transposition Schemes.*

It would be possible to fulfill the conditions for balance with regard to induction arising from balanced currents and voltages, by cutting a " barrel " into the power circuit between successive communication circuit transpositions. Inasmuch as telephone transposition points are ordinarily spaced at one-fourth mile intervals, this solution in the case of a three-phase power circuit would necessitate transpositions at an average spacing of one-eighth mile and a minimum spacing of one-twelfth mile, which is impracticable in most cases.

It would be possible to satisfy the conditions for balancing the induction in metallic circuits, from both balanced and residual currents and voltages, by installing any completely balanced system of communication circuit transpositions between each two successive power circuit transpositions. Assuming twelve-mile " barrels " in the power circuit, the conditions for balance could be fulfilled with the present standard telephone transposition system. However, with power circuit barrels of a length such as is essential in most parallels, this solution would require the redesign and relocation of all telephone transpositions in the exposure, involving several times as many transpositions as are normally require, with the liability of interference with the location of loading coils.

Both the above solutions satisfy the conditions for balancing the induction in metallic circuits, arising from residuals, in a length of circuit equal to twice the distance between successive communication circuit transpositions, assuming these are uniformly spaced. In the standard transposition section as now used, balance is thus obtained in distances varying from an average of approximately one-half to four miles.

Between these two comparatively simple but extreme solutions the practical but more complicated solution for general cases is to be obtained. This involves the combination of power circuit barrels of moderate length with a modified communication circuit transposition system designed to procure balance as far as practicable for all circuits. In this way coordinated transposition systems may be designated which are sufficiently flexible

to meet the requirements of short parallels and portions of longer parallels separated by points of discontinuity.

In the discussion above with reference to schemes of transpositions, the balances or unbalances mentioned are those which would occur, due solely to the relative locations of transpositions, in an exposure whose physical characteristics are uniform throughout. Even with a scheme of transpositions, balanced in the sense described, applied to both power and communication circuits involved in an actual parallel, there are a number of factors as noted below, which in general are not capable of being taken into account quantitatively and because of which effective neutralization may not be obtained. These factors are:

1. Non-uniformity of separation, configuration and other physical characteristics.
2. Variation in magnitude and phase of the inductive effects along the exposure (applying particularly to the higher frequencies.)
3. Inherent inability of transpositions to completely neutralize electrostatic induction (this remanent effect can be reduced as far as desired by inserting a sufficient number of transpositions.)
4. Imperfect electrical balance of the communication circuit.

While these factors which prevent complete neutralization of the induction cannot be entirely eliminated, their effects can be abated by reducing the length of balanced transposition sections. Thus it is not sufficient merely to install transpositions in both lines so that they are balanced to each other, but, also, it is necessary to take into consideration the length of section within which balance is obtained and to make this length as short as the conditions of the particular case require.

Points of discontinuity, such as abrupt changes in power line current where a material amount of load is taken off, cross-overs, or substantial changes in separation, should, if practicable, be made neutral points (junction points of balanced sections) in the transposition scheme. Where cross-overs occur balance should in general be obtained independently for the portions of the communication line on each side of the power circuit.

The transposition system and the location and spacing of transposition poles are factors of prime importance in the successful operation of telephone lines, on account of the mutual effects among the many circuits carried on such lines. On the other hand, transpositions in power circuits are, relatively, of minor importance in the operation of a power system and from this standpoint the effect of small changes in the location of such transpositions is negligible. Hence, in general, the requirements

of the communication circuits are the chief factors which should govern the location of all transpositions in both power and communication circuits.

An individual study is necessary to determine the best procedure for any given parallel owing to the wide variation in conditions. Thus only is it possible in each case to determine the best location and method of transpositions with regard to the requirements of both power and communication systems.

4. *Results of Tests.*

The investigation at Salinas demonstrated that the induction in a ground return circuit in the exposures concerned, arises principally from the residual voltages and currents while the induction in a metallic circuit shows principally the characteristics of the balanced voltages and currents together with some effect from the residuals. This result was to be expected as there are power circuit transpositions which reduce the induction in the conductors used as ground return circuits, due to the balanced components, but these transpositions and the transpositions in the telephone circuits are improperly located with respect to each other and therefore are inefficient as regards the induction in the metallic circuits. On the other hand, the telephone transposition system tends inherently to reduce the induction in the metallic circuits, arising from residuals. A study of the relative location of power and telephone circuit transpositions for exposure No. 2 at Salinas, indicated that by modifying the present transpositions of both circuits, it is possible to reduce materially the induction from balanced currents and voltages. Had it been feasible to take the power circuit out of service for the purpose of experimental retransposition, the above scheme, as well as one for the King City exposure, would probably have been installed and the effects thereof experimentally determined. Under the conditions existing, however, it was deemed advisable to postpone the matter of transpositions for both these exposures, pending the acquisition of further information as to the extent to which retransposition would be warranted as a permanent improvement.

The experimental study of transpositions was, therefore, transferred to another point where a power line is not the sole source of supply and can, therefore, be shut down for alterations and tests under special conditions.

The experimental determination of the practical effectiveness of transpositions has not been completed. However, an ex-

tended theoretical study of transpositions has been made, including the design of a modified telephone transposition system. This system which requires many additional transpositions is more flexible in its properties of coordination with different lengths of power circuit "barrels".

A study made to determine the relative efficiency of various schemes of transpositions designed for the Santa Cruz-Watsonville exposure of The Pacific Telephone and Telegraph Company's toll lead to the 22,000-volt line of the Coast Counties Gas and Electric Company, emphasizes the following general principles:

1. The necessity of proper relative location of power and telephone circuit transpositions.
2. The importance of the effect of cross-overs and the desirability of making them neutral points in the transposition scheme.
3. The necessity of some modification of the telephone transposition system.

APPENDIX IV

Apparatus

For the proper conduct of its tests and experiments the Joint Committee on Inductive Interference has secured either through purchase or on loan account from various power and communication interests apparatus of an aggregate value of over twelve thousand dollars.

The following is a brief schedule of the property in use by this Committee together with its estimated replacement value:

Buildings (Portable Laboratory)		$ 480.00
Furniture and Fixtures		128.00
Apparatus—Oscillograph	$1,115.00	
Oscillator	600.00	
Motor-Generator Set	260.00	
Meters	1,202.50	
Batteries	100.00	
Condensers	990.00	
Bridges	675.00	
Galvanometers	265.00	
Rheostats	734.80	
Switchboards	135.40	
Misc. Apparatus	1,505.00	
Coils and Relays	645.00	
Transformers	2,412.50	
Miscellaneous	787.00	
Photographic	293.60	11,820.80
Grand Total		$12,428.80

The above property is owned by the Joint Committee on Inductive Interference and various power and communication companies, as follows:

Joint Committee on Inductive Interference	$ 1,251.15
The Pacific Telephone and Telegraph Company and American Telephone and Telegraph Company	8,293.65
Sierra and San Francisco Power Company	2,002.50
San Joaquin Light and Power Company	300.00
Pacific Gas and Electric Company	110.00
Western Union Telegraph Company	235.00
Testing Force	256.50
Total	$12,428.80

APPENDIX V

List of Technical Reports

The following is a list of the technical reports which have been prepared in connection with the investigation of the Joint Committee on Inductive Interference:

Technical Report No. — Subject

1. General outline of tests to be made at Salinas on parallels between lines of the Sierra and San Francisco Power Company, the Western Union Telegraph Company, the Southern Pacific Company, and The Pacific Telephone and Telegraph Company. (6 pages.)
2. Summary of results of tests at Morganhill on parallel between lines of the Coast Counties Gas and Electric Company and The Pacific Telephone and Telegraph Company between Morganhill and Gilroy. (8 pages.)
3. A description of the noise standard in use for measuring noise on telephone circuits in terms of a standard unit. (4 pages)
4. A description of the instruments and methods used for the measurements of effective values of induced voltages and currents. (2 pages.)
5. A description of apparatus and connections used in measuring line and residual currents and voltages of power circuits. (6 pages)
6. Tests of the effects of opening the secondary delta of the auto-transformer bank at Salinas. (7 pages)
7. Tests of the induction in the block signaling circuits of the Southern Pacific Company paralleled by the Salinas-King City circuit of the Coast Valleys Gas and Electric Company. (4 pages.)
8. Tests of the induction in the telephone circuits of exposure No. 2 at Salinas under normal operating conditions of the power system, with particular reference to the effects of grounding and isolating the neutral of the Salinas auto-transformers. (16 pages)

9. Experimental determination of the coefficients of induction for residual currents and voltages in exposure No. 2 at Salinas. (4 pages.)

10. Measurements of the harmonics of the neutral current at Salinas. (4 pages.)

11. Investigation of current transformers, ratios, and errors due to the use of current transformers under the conditions of the tests. (21 pages)

12. Formulae for the computation of electrostatic and electromagnetic induction from power circuits in neighboring communication circuits. (18 pages)

13. An investigation of errors in measurements of residual voltage due to the potential transformers used and a discussion of the method of measurement at Salinas. (30 pages)

14. Comparative tests of the noise in exposed telephone circuits with power on and off the 55,000-volt power circuit of the Sierra and San Francisco Power Company between Guadalupe and Salinas. (8 pages)

15. Supplementary to Technical Report No. 8, differing from the earlier report in that the telephone circuits were shielded. Contains a discussion of transpositions. (22 pages)

16. Tests of the induction in telephone circuits exposed to the Coast Counties Gas and Electric Company's 22,000-volt line between Morganhill and Gilroy with the power circuit untransposed and open at Gilroy. (4 pages)

17. Tests of the induction in telephone circuits exposed to the Coast Counties Gas and Electric Company's 22,000-volt line between Morganhill and Gilroy, before and after installing power circuit transpositions. (24 pages)

18. Tests of the effect, on exposed telephone circuits, of grounding one phase of the Coast Counties Gas and Electric Company's 22,000-volt three-phase delta-connected line. (4 pages)

19. Test of the combined effects of the Coast Counties Gas and Electric Company's and the Sierra and San Francisco Power Company's circuits on the telephone circuits in the exposure between Morganhill and Gilroy. (4 pages)

20. Tests of the effect on the residual voltage of transposing the Coast Counties Gas and Electric Company's 22,000-volt line within the exposure between Morganhill and Gilroy. (3 pages)

21. Tests to determine the comparative effect on the noise in the exposed telephone circuits of having the power on and off the Coast Counties Gas and Electric Company's 22,000-volt line between Morganhill and Gilroy, and the effect of shielding the telephone circuit under test by grounding other circuits on the lead. (4 pages)

22. Computation of the coefficients of induction from balanced and residual currents and voltages for the telephone circuits of exposure No. 2 at Salinas. (19 pages)

23. Experimental determination of the coefficients of induction from residual currents and voltages, for the telephone circuits of exposure No. 2 at Salinas—more complete than Technical Report No. 9. (24 pages)

24. Comparison of computations of Technical Report No. 22 with experimental data of Technical Report No. 23. (16 pages)

25. Tests of induction in telephone circuits in exposure between Salinas and King City under normal operating conditions, with the neutral of the Salinas auto-transformers grounded and isolated. (20 pages)

26. Tests of accuracy of measurement of residual current by certain current transformers. (4 pages)

27. Tests of induction in telephone circuits in exposure No. 2 at Salinas with the North Beach steam station energizing the Sierra and San Francisco Power Company's line. Supplementary to Technical Reports Nos. 8 and 15, differing in the source of supply of the power system. (27 pages)

28. Supplementary to Technical Reports Nos. 8 and 15. Voltage lowered 5 per cent at the Guadalupe auto-transformers which supply the power circuit. (20 pages)

29. Determination of impedances of lines, by computations and by measurements—numerous curve sheets and tables. (65 pages)

30. Tests of induction in telephone circuits in exposure Nos. 1 and 2 at Salinas, with the neutral of the Salinas transformers grounded and isolated. (10 pages)

31. Supplementary to Technical Reports Nos. 8 and 15 and more complete. Includes tests with Salinas neutral grounded and isolated and with telephone circuits shielded and unshielded. (29 pages)

32. Supplementary to Technical Report No. 25. (22 pages)

33. Induction in test leads used at Salinas for connecting testing apparatus to the circuits of exposure No. 2 and the effect of such on the measurements of the induction from the exposure. (20 pages)

34. Effect of changes in the insulation resistance of the telephone line on the induction in telephone circuits of exposure No. 2 at Salinas. Also supplements Technical Reports Nos. 8, 15, and 31. (24 pages)

35. General outline of tests to be made at Santa Cruz on the parallel between lines of the Coast Counties Gas and Electric Company and The Pacific Telephone and Telegraph Company. (4 pages)

36. Induction in telegraph circuits of the Western Union Telegraph Company and the Southern Pacific Company in exposure No. 1 between Salinas and San Jose. (8 pages)

37. Noise tests on telephone circuits radiating from Salinas, with the neutral of the Salinas auto-transformers grounded and isolated. (4 pages)

38. General review of tests at Salinas, summarizing reports, 1, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 22, 23, 24, 25, 26, 27, 28, 30, 31, 32, 33, 34, 36, and 37. (53 pages)

39. General consideration of transpositions and a study of the results to be expected from the application of various transposition schemes to the Santa Cruz-Watsonville exposure. (36 pages)

40. Method of measurement of capacity and conductance unbalances (2 pages)

41. Harmonic analysis of alternating-current waves, by oscillograph and resonant shunt. Comparison of the methods. (30 pages)

42. Investigation of the current transformers in use at Santa Cruz. to determine their ratios of transformation and suitability for residual current measurements. (35 pages)

43. Outline of tests to determine the effect of extraneous currents on the intelligibility of telephone conversation. (8 pages)

44. Induction in the telephone circuits of the Santa Cruz-Watsonville exposure and in the test leads, from sources other than the 22,000-volt line. (12 pages)

45. Induction in the telephone circuits of the Santa Cruz-Watsonville exposure under commercial operating conditions, with the original transpositions in both power and telephone lines. (15 pages)

46. Supplementary to Technical Report No. 39. A study of additional transposition schemes for the Santa Cruz-Watsonville exposure. (14 pages)

47. Computation of the coefficients of induction for balanced and residual currents and voltages for the Santa Cruz-Watsonville exposure. (11 pages)

48. Experimental determination of coefficients of induction in the Santa Cruz-Watsonville exposure, with the original transpositions. (42 pages)

49. Further experimental determination of coefficients of induction for balanced voltages, in the Santa Cruz-Watsonville exposure, with the original transpositions. (13 pages)

50. Study of the influence of various transformer connections and flux densities on the third harmonic and its multiples in a three-phase circuit. (in preparation).

APPENDIX VI—ORGANIZATION—JOINT COMMITTEE ON INDUCTIVE INTERFERENCE. JUNE 15, 1914

CHAIRMAN
R. SACHSE

SUB-COMMITTEE ON FINANCE
CHAIR.-R. SACHSE
P. M DOWNING
V. V. STEVENSON

SUB-COMMITTEE ON PROGRAM
CHAIR-A. H. GRISWOLD
A. H. BABCOCK
R. W. GRAY

SUB-COMMITTEE ON TESTS
CHAIR-J. E. WOODBRIDGE
A. H. GRISWOLD
A. H. BABCOCK
R. W. GRAY
J. A. KOONTZ
F. E. HOAR

ACT'G. SEC'Y.
R. W. MASTICK

STENOG.
L. MAHONEY

TREAS.
F. E. HOAR

SUB-COMMITTEE ON PUBLICITY
CH.-A. H. BABCOCK
J. E. WOODBRIDGE
A. H. GRISWOLD

SUB-COMMITTEE ON PUBLICATION
CHAIR. R. W. MASTICK
J. A. KOONTZ
V. V. STEVENSON

SUB-COMMITTEE ON NOMINATIONS
CHAIR.- R. SACHSE
R. W. MASTICK
J. E. WOODBRIDGE
R. W. GRAY

FIELD ENGINEERING STAFF

ENGINEER IN CHARGE
R. W. MASTICK

ASS'T. ENGINEER IN CHARGE
L. P. FERRIS

STENOG.
J. R. NEWLOVE

ENGINEERS
L. N. ROBINSON
C. A. TURNER
D. I. CONE
R. G. McCURDY

DRAFTSMAN & PHOTOGRAPHER
E. G. DOLDER

ENGINEERS FORMERLY ON FIELD STAFF

A. J. CHAMPREUX	S. H. HESS
H. S. OSBORNE	F. E. PERNOT

MEMBERS

R. SACHSE	J. E. WOODBRIDGE
F. E. HOAR	J. P. JOLLYMAN
A. L. WILSON	A. H. BABCOCK
P. M. DOWNING	A. H. GRISWOLD
J. A. KOONTZ	R. W. MASTICK
H. A. BARRE	C. H. TEMPLE
R. W. GRAY	V. V. STEVENSON

HONORARY MEMBERS
H. S. WARREN
J. T. SHAW

To be presented at the Pacific Coast Meeting of the American Institute of Electrical Engineers, Spokane, Wash., Sept. 9-11, 1914.

(Subject to final revision for the Transactions.)

150,000-VOLT TRANSMISSION SYSTEM

SOME OPERATING CONDITIONS OF THE BIG CREEK DEVELOPMENT OF THE PACIFIC LIGHT & POWER CORPORATION

BY EDWARD WOODBURY

ABSTRACT OF PAPER

The paper describes operating conditions on the 150,000-volt transmission line of the Pacific Light and Power Corporation which delivers power from the Big Creek hydroelectric development to Los Angeles, Cal., 240 miles away. In daily operation 60,000 kw. are generated, utilizing a total hydraulic head of 4000 ft., in two steps. Plans for the future contemplate the building of two more power houses, operating under somewhat lower heads.

Of particular interest is the complete success of the constant potential system, *i. e.*, operation at the same voltage at the generating and receiving stations, by means of synchronous condensers at the receiving end, in conjunction with automatic voltage regulators, one for each condenser as well as for the generators at each of the power houses. The line has been operated with unusual freedom from short circuits.

Appendixes describe the development of the system, and give data relating to the equipment of the Big Creek transmission line.

THE most striking feature of the Big Creek development and transmission is the magnitude of the figures in which the plant data are expressed. In daily operation, 60,000 kw. are generated, utilizing a total hydraulic head of 4000 ft. (1219 m.) in two steps, and transmitted 240 miles (386 km.) at 150,000 volts, thus entailing some conditions of operation which are rather striking.

The transmission line is of course the element of greatest importance in satisfactory commercial operation, although there are many features of engineering interest in the generating and receiving parts of the system.

The most critical problem to be solved proved to be that of regulation. It must be remembered that the inherent regulation of the line alone, without terminal equipment, is from 10 per cent above power house voltage at no load, to 20 per cent below at full load; that the effect of the transformer inductive

reactance at the generating end practically doubles the boosting at light load, and that the self-exciting characteristics of the generators, when supplying charging current only, tend to produce abnormal voltages at light load.

The complete success of the constant potential or zero regulation system, *i.e.*, operation at the same voltage at the generating and receiving stations, is of particular interest. This result is obtained by the use of synchronous condensers at the receiving end, in conjunction with automatic voltage regulators, one for each condenser as well as for the generators at each of the power houses. Since there are two 15,000-kv-a. condensers and four 17,500-kv-a. generators to be controlled, the regulator problem received most serious consideration, and was made the subject of careful experiment under working conditions before being proved satisfactory, as it now is. It has been

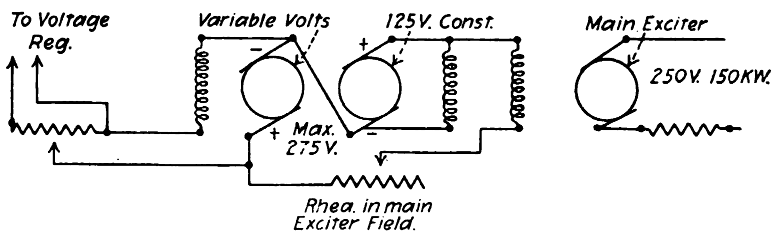


FIG. 1—EXCITER CONNECTION, PLANT NO. 1, BIG CREEK.

found necessary to arrange the regulators to control field currents from a maximum to zero.

In one generating station the excitation system consists of three direct-current units, one of which is the exciter proper, the other two being connected in series opposition, and used to excite the field of the main exciter. See Fig. 1. The two units making up the secondary exciter are designed to generate 125 volts and 275 volts respectively. With a potential regulator on the 275-volt unit, arranged with auxiliaries to prevent a reversal of the field in the 125-volt unit of this set, the voltage applied to the exciter field may be changed from that required to give maximum excitation to zero excitation, within a range of voltage on the 275-volt unit, which can be readily handled by the standard alternating-current automatic voltage regulator.

The alternators at the other generator station are excited directly by 200-kw., 250-volt exciters, the main field of which

is controlled by a new type of alternating-current automatic voltage regulator, which has no direct-current magnet and which can therefore be adjusted to reduce the exciter voltage to zero. The exciters on this system have three shunt windings on the field, as shown in Fig. 2. One auxiliary field is provided to give the reversed excitation necessary to hold the voltage down when charging the line, the current being supplied to this field, through a variable resistance, by means of a storage battery. The other auxiliary field, which is solely for the purpose of maintaining the correct polarity, also takes its current, which is small, from the same storage battery.

A reduction of the excitation to zero by means of the potential regulator, has not been necessary at the generating stations, but operation of the synchronous condensers at the receiving

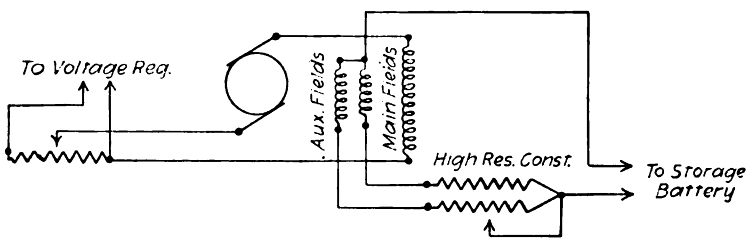


FIG. 2—EXCITER CONNECTION, PLANT NO. 2, BIG CREEK.

station, over the range required, would not be feasible without a complete reduction of the exciter voltage.

With 150,000 volts at the receiving end of the line, the charging current is about 40 per cent overload for one generator. With normal voltage of 6600 volts at the generator, the charging current overloads the generator 65 to 70 per cent. Hence in normal operation a line is usually energized by using two generators, under which condition a small field excitation in the normal direction is required. Abnormal conditions sometimes make it necessary to charge the line from a single generator, until the condensers at the receiving station can be started.

The self-exciting characteristics of the system with leading current are such that in one of the generating stations a single 6600-volt generator, when connected to an unloaded line without its condenser and run at normal speed with the field switch open, would excite itself to 7000 volts, corresponding to 176,000 volts on the transmission line at the generating station, and

demand from the generators 34,000 kv-a. and 850 actual kilowatts.

At the other station, where the generators were designed by a different manufacturer and had slightly different characteristics, the results were greater and the self-excitation under similar conditions would reach 9000 volts at the generator or 230,000 volts on the line at the generating end. For this con-

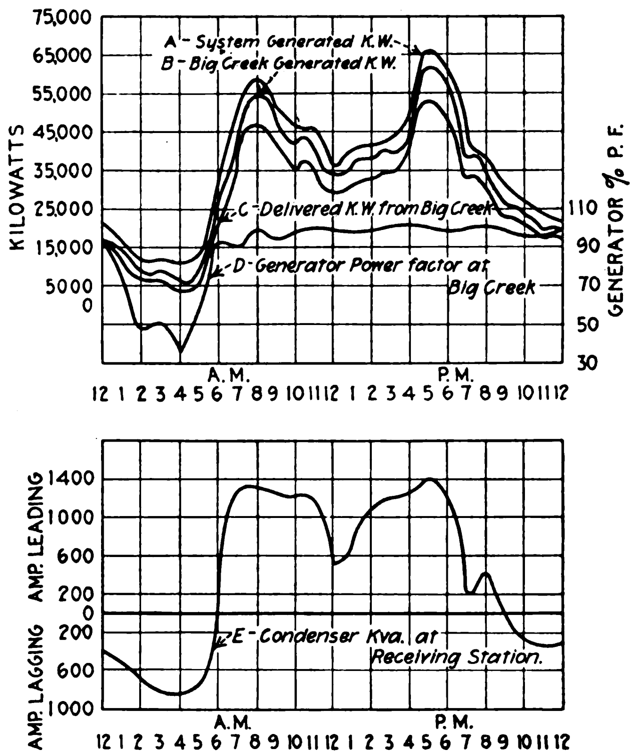


FIG. 3—TYPICAL DAILY OPERATING CURVES OF BIG CREEK SYSTEM, WITH ZERO LINE REGULATION.

dition the generator would have to deliver 5000 kw. and about 50,000 kv-a.

Means had therefore to be furnished for using current in a reverse direction in the generator fields to counteract the excitation due to the leading current.

The curves of Fig. 3 show typical daily operating conditions as follows:

(A) System-generated kilowatts.
(B) Big Creek-generated kilowatts.
(C) Delivered kilowatts from Big Creek.
(D) Generator power factor at Big Creek.
(E) Condenser kilovolt-amperes at receiving station.

The difference between A and B is on account of other generating stations being in operation on the system and being used to the limit of their capacity for correction of load power factors.

The speed regulation by the waterwheel governor has been excellent, so that no complications have arisen from this source.

As might be expected with a system of this magnitude, special consideration has been given to minimizing the effects of short circuits. Accordingly, the reactance of the generators of the two manufacturers has beeen made 70 per cent and 85 per cent respectively; of generating station transformers 5 per cent and 8.5 per cent; of receiving station transformers 5 per cent and 8.5 per cent. The result is that the instantaneous short-circuit current is only 330 per cent of full load on the generators and the sustained short-circuit current 110 per cent with normal excitation of full load. Under these conditions the waterwheel governors shut off water on short circuit before any serious change in speed can take place.

On account of the use of aluminum cable for the transmission line, it is very desirable to suppress an arc on the line before the wire can be seriously injured; and there is now under consideration the installation of a field-killing relay to be installed in the neutral of the generating station transformers, which will very quickly extinguish the arc and automatically permit the restoration of voltage immediately.

Of the short circuits which have occurred, none have been sufficiently serious to burn down the cable. Some of the outer strands have been scorched, but not sufficiently so to diminish strength. The scorched sections are of course removed at the earliest opportunity.

The causes of the short circuits, which have occurred, may be stated as follows:

1. In the rush of construction, a tree was left standing too close to the line and blew against it. The cable was scorched, but not seriously hurt. This occurred during the tryout period, and while the voltage was returned to normal in a fraction of a minute, the load was transferred to the steam plant, for some

time, while experimenting was done to endeavor to locate the trouble.

2. An irrigator tried to clean out a well near the line with a heavy charge of dynamite, blowing a lot of mud and water into the line. The current arced to the ground cable, but did not seriously injure the transmission cable.

3. One of the insulators on a disconnecting switch in one of the stations flashed over.

4. Seven other line short circuits have occurrred, five of which have been found to be due to flash-over of insulators, one to be due to an arc from line to a tree during high wind, and the location and cause of the other has not been discovered. In every case of the above, trouble was cleared by reducing the voltage at generators upon current being observed in the ground ammeters, after which service was immediately resumed.

In all cases of insulator flash-overs, the damage to insulators was so slight that service could be resumed, without repairs, immediately on extinguishing the arc. In two cases, two disks out of the string of nine were broken down or badly shattered. In the third case, two of the disks were slightly chipped on the edge.

In the remaining two cases the arcing bars with which the insulator hardware is furnished (see Fig. 4), protected the insulators against any damage. It is found that a flash-over will sometimes burn from one to two inches off the end of the arcing bar, and apparently does not go to the cable unless the direction and strength of the wind are such as to carry the arc out along the cable. The separation of the arcing bars is 51 in. (129.5 cm.), equivalent to a break-down potential of over 500,000 volts at normal frequency.

5. The most serious line interruption was caused by a mechanical defect in a dead-end clamp at the end of a 2700-ft. (823-m.) span across a wide and deep river. The weight and tension of the cable make a repair of this kind a serious matter. The clamp which failed was one out of 5000, so the percentage is not high.

Various features of the system have been described in detail in different technical journals and do not need repetition, but, for convenience, appendixes follow, showing how the growth of the Pacific Light & Power Corporation system made an installation of the magnitude of Big Creek an economic possibility, and giving the principal physical data of the develop-

ment. The author desires to thank Mr. H. A. Barre and Professor R. H. Sorensen for their generous assistance in the preparation of this paper.

APPENDIX I

HISTORICAL

In 1897 the San Gabriel Electric Co. built at Azusa a hydro-electric plant consisting of four 300-kw. generators, which received their energy from a small stream with a 400-ft. (122-m.) head. The water power converted into electric energy by these generators at a potential of 500 volts was transformed to a potential of 15,000 volts and transmitted at this potential a distance of 25 miles (40 km.) to Los Angeles. Later, four other small hydroelectric plants varying in size from 150 kw. to 1500 kw. were added, and a "standby" steam plant of 2000 kw. was constructed, giving a total capacity of 6000 kw., 4000 kw. of which was water power.

January 1, 1905, the Kern River plant, a hydroelectric plant made up of five 2000-kw. generators, which transmitted its energy over 125 miles (201 km.) of line at a potential of 60,000 volts, was developed, and two years later, the original Redondo steam plant, which at that time made such a record for efficiency, was completed and its 15,000 kw. contributed to the service of the community. Even this, however, was not sufficient, for in 1911 it was found necessary to add to Redondo two 12,000-kw. turbine units, thus bringing up the available capacity of the system to 55,000 kw.

Even this tremendous supply of power rapidly became insufficient to meet the demand, and the company prepared to carry out the development of the now famous Big Creek project, which was to convert the energy available in Big Creek into electric energy and transmit it 240 miles (386 km.) to Los Angeles.

To transmit electric energy over such a distance with economy requires, of course, the highest practical potential, which in this case was selected as 150,000 volts, and plans for transmission at this voltage were drawn. These plans called for the immediate development of 60,000 kw. maximum, delivered at this voltage to the Los Angeles receiving station known as Eagle Rock substation.

This energy is generated by four 17,500-kv-a., 6600-volt

generators, two in each power house. At Power House No. 1 the water is delivered to the wheels under an average head of 2050 ft. (624.8 m.) from a reservoir about five miles (8 km.) long and one mile (1.6 km.) wide, with sufficient storage capacity to operate the plant at full load about four months, which is equivalent to six or eight months of operation based upon a 60,000-kw. peak on the two plants. After leaving Power House No. 1 the water enters a second tunnel, whence it is carried 4½ miles (7.2 km.) to Power House No. 2, where it is delivered at an average head of 1857 ft. (565 m.).

Projected Development

Each of the two present power houses is so designed that its capacity may be doubled, simply by raising the height of the storage dam and installing the necessary generators, waterwheels, transformers and switching equipment. Future plans contemplate the erection of two other power houses, each as large as No. 1 and No. 2 will be when completed, at a lower elevation. These will operate under a somewhat lower head than power houses No. 1 and No. 2, but the difference in head will be supplemented by the addition of more water.

Construction

In order to take up the construction of the Big Creek project, it was necessary to construct 56 miles of standard-gage railroad over a very mountainous country, where even with the many curves the average grade is over 4 per cent. Materials were hauled over this track to the power house sites with shay locomotives, very often three engines being applied to a four-car train of heavy machinery.

It was also necessary to build two inclined railways, one to transport material from the end of the railway to the reservoir site and one to let material down to power house No. 2 from the railroad. When the work was at a maximum of activity 3500 men were employed, all of whom were housed in fifteen camps located in the mountains a long distance from supplies.

APPENDIX II

Equipment Data

Two power plants, total capacity 64,000 kw.
Four 17,500-kv-a. generators.
Eight tangential waterwheels, each pair develops 16,000 kw.

[WOODBURY]

FIG. 4—150,000-VOLT SUSPENSION INSULATOR, SHOWING ARCING RODS.

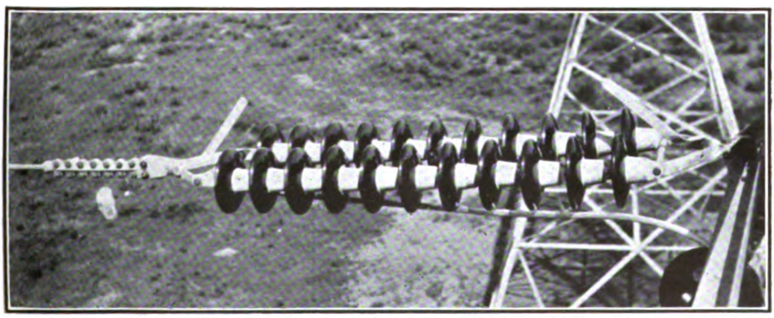
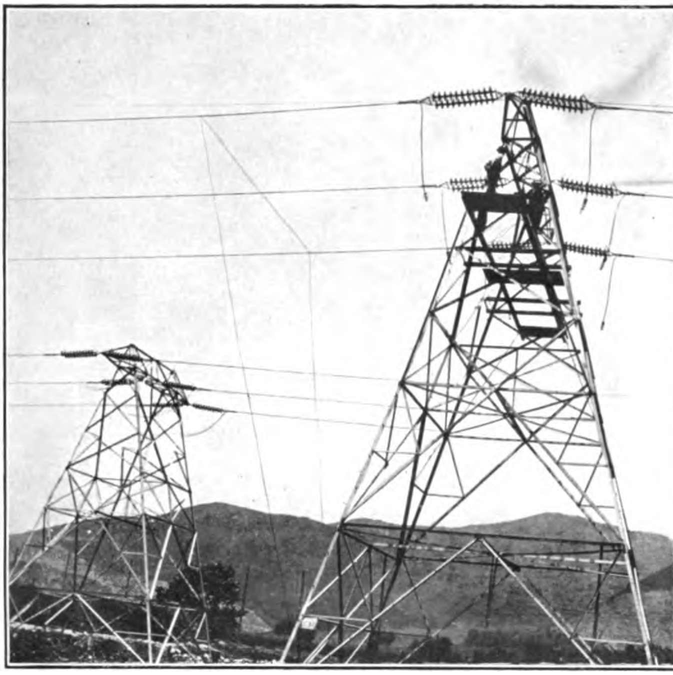
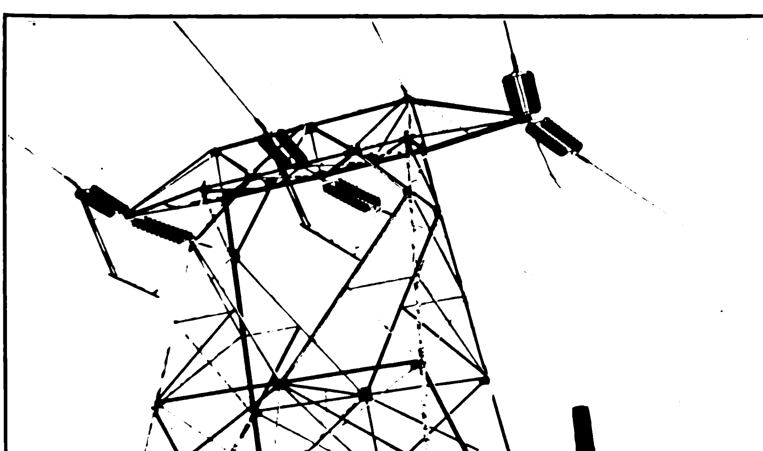


FIG. 5—150,000-VOLT STRAIN INSULATOR. [WOODBURY



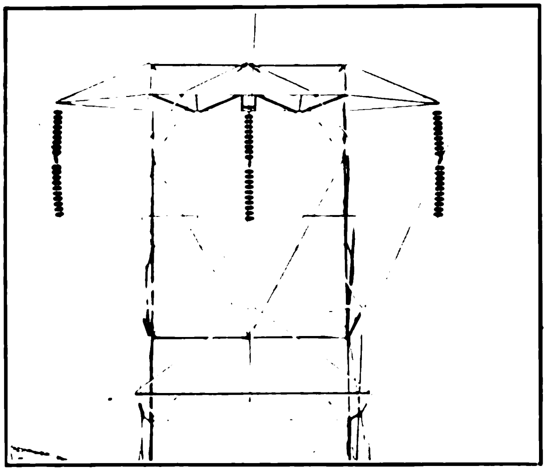
[WOODBURY]

FIG. 6—TYPICAL DEAD-END TOWER USED FOR LINE SECTIONALIZING BY OPENING JUMPER LOOP.



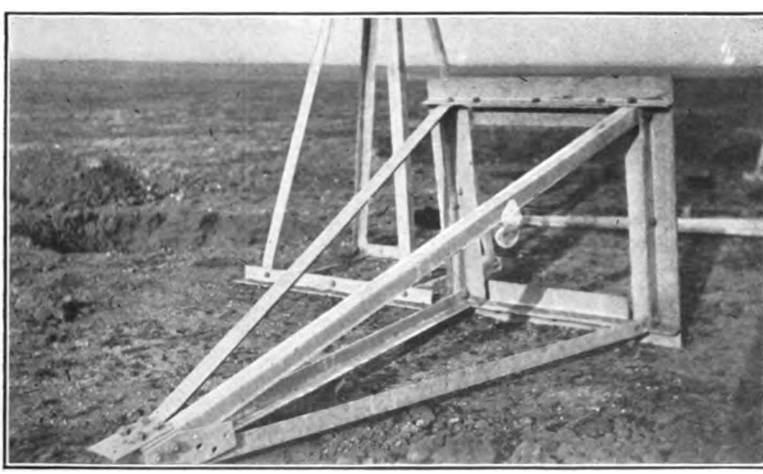
[WOODBURY]

FIG. 7—ANGLE TOWER, SHOWING BRACKET TO PREVENT LOOP FROM SWINGING.



[WOODBURY]

FIG. 8—METHOD OF TYING DOWN CONDUCTORS TO PREVENT UPLIFT IN COLD WEATHER.



[WOODBURY

FIG. 9—STEEL FOOTING FOR STANDARD TOWER.

One generator, full load, 24 hours, uses 240 acre-feet of water.
Maximum head of water plant, No. 1, 2100 ft. static. Plant No. 2, 1900 ft.
Reservoir capacity, initial development, 51,600 acre-ft. Cubic yards concrete in dams, initial development, 120,000.
Reservoir will operate plants 220 days on 50 per cent load factor.
Drainage area 88 square miles.
Five miles of 12-ft. tunnels through solid rock.
Single-phase transformers, largest yet built, weigh 81 tons and contain 10,000 gal. of oil.
Power station transformers connected delta 6600 volts, Y 150,000 volts, with grounded neutral.
Receiving station transformers connected delta 150,000 volts, delta 60,000 volts and 18,000 volts respectively.
Two 15,000-kv-a. synchronous condensers at receiver end each require 10,000 kv-a. to start.
Under no-load conditions, 137,000 volts at generator rises to 150,000 volts at receiver.
Charging current is 90 amperes at 137,000 volts, equals 21,500 kv.-a.
Fifty amperes reversed excitation necessary to bring generator "down on line" to zero potential, no-load condition.
Power factor of generators is high, being above 95 per cent the greater part of the day.
Current is unbalanced approximately 12 per cent under no-load conditions on account of the conductors being in horizontal plane.
Under normal load conditions, above 12 per cent is reduced at approximately 2 per cent.
A potential of 4200 volts is induced in a dead section of the duplicate line 100 miles in length, distant 82 ft. center to center.
Line loss at full load is 9 1/2 per cent. In addition there is 5 per cent loss in transformers, auxiliaries, etc.

Data on Big Creek Transmission Line

General:

Length, 240.41 miles power house No. 1 to Eagle Rock substation, plus 0.74 mile tap to power house No. 2, total 241.15 miles.

Voltage, 150,000 volts, 50 cycles.

Number of tower lines, 2.

Number of circuits per tower line, 1.

Capacity of each circuit, 57,500 kw. at 0.85 power factor for 11 per cent regulation using two synchronous condensers.

Right of Way:

Width of right of way, 150 feet.

Separation of center lines of tower lines, 82 ft.

Towers:

Normal spacing in valleys where no sleet occurs, 660 ft.

" " " " " sleet occurs, 550 ft.

Maximum span, 2871 ft. (Sunland), 2776 ft. (Kings River).

Maximum span on standard towers, 1822 ft.

Maximum angle on standard tower, 0 deg. 49 min. (Normal span no sleet 1 1/2 deg. plus wind). Insulators take 45 deg. position.

Maximum angle on anchor towers, 48 deg. designed for 60 deg. 114 deg. 2 min., under special conditions at tower No. 1.

Total number of towers, both lines, 3388.

Average number of towers per mile, single line, 7.08

Classification	Standard	Anchor and Angle	Special
Weight above foundation.	4300	6450	4485
Weight of steel footings ..	1305	1605	1305
Total steel per tower.....	5605	8055	5790
Spread at base with line.	20 ft.	24 ft.	20 ft.
" " " across line	18 ft.	24 ft.	18 ft.
Height above ground to insulation support....	43 ft.	37 ft.	43 ft.

Unit Stresses:

Tension = 20,000 lb. per sq. in.

$$\text{Compression} = \frac{16,000}{2} \text{ lb. per sq. in.}$$

$\frac{L}{R}$ for corner posts, 125.

$\frac{L}{R}$ for bracing, 175, except where a larger value is approved by the purchaser.

Minimum thickness of members, 3/16 in.

Unit stress in bolts:

Shear............15,000 lb. per sq. in.

Bearings.........30,000 lb. per sq. in.

Design Assumptions:

Standard Towers:

(1) Wind load, 22 ½ lb. per sq. ft. of exposed area, with or at right angles to the line; wind pressure simultaneously applied to both faces of tower, and

(2) A pull in the direction of the line of 4250 lb. at the points of support of two adjacent conductors pulling on the same side of the tower, and

(3) A vertical load of 1000 lb. at each conductor support where conductor is unbroken, and of 530 lb. at each ground wire support, and of 500 lb. if conductor is broken, and

(4) A wind load of 600 lb. at right angles to the line at each conductor support where conductor is unbroken, and of 300 lb. at right angles to the line at each conductor support where conductor is broken, and of 500 lb. at each ground wire support.

The above loads are simultaneously applied.

Ground wire support designed to withstand an unbalanced pull of 5000 lb. in the direction of the line.

Anchor and Angle Towers:

Anchor and angle towers are designed for each of the following groups of conditions, only one of which groups is to be taken at a time:

I. (1) A wind load of 22½ lb. per sq. ft. of exposed area, with or at right angles to the line; wind pressure applied simultaneously to both faces of tower, and

(2) A pull in the direction of the line of 8000 lb. at each of the three conductor supports, on either side of tower, and of 8000 lb. at each ground cable support, and

(3) A vertical load of 500 lb. at each of the three conductor supports and of 265 lb. at each ground cable support, and

(4) A wind load of 300 lb. at each of the three conductor supports, and of 250 lb. at each ground cable support.

II. (1) A wind load of 22½ lb. per sq. ft. of exposed area, with or at right angles to the line; wind pressure applied simultaneously to both faces of tower, and

(2) A pull at right angles to the line of 8000 lb. at each of the three conductor supports, and of 8000 lb. at each ground cable support, and

(3) A vertical load of 1000 lb. at each of the three conductor supports and of 530 lb. at each ground cable support, and

(4) A wind load of 600 lb. at each of the three conductor su pports and of 500 lb. at each ground cable support.

Number of conductors supported by each tower, 3.

Arrangement, in same horizontal plane.

Number of lightning ground wires, one at first; space for two if needed.

Smallest size angle iron used, 1¾ by 1¾ by 3/16 in.

Conductor:

Material, aluminum with steel core; steel double-galvanized.

Composition Metals	No. strands	Cir. mils.	Weight per mile	Weight per foot	Elastic limit square inch	Ultimate tensile strength sq. inch
Aluminum......	54	605,000	2940	....	13,000	26,000
Steel...........	7	78,500	1118	....	115,000	195,000
Total.........	61	683,500	4058	0.77		33,600

Total resistance 35 ohms per leg.

Maximum working tension allowed—13,000 lb. per sq. in. in aluminum.

Stringing tension at 80 deg. fahr.

Ice allowance................3130

No ice allowance 4740

Type of joints, McIntyre sleeve on steel inside of compression aluminum sleeve.

Ground clearance:

On right of way...............25 ft. at 140 deg. fahr.

At crossings..................Legal, as required.

Ground Wires:

Number per tower, 1.

Size, $\frac{1}{2}$ in. 7-strand.

Material, Siemens-Martin steel.

Breaking tension, 13,000 to 15,000 lb.

Maximum working tension allowed, 6500 lb. sleet—2100 ft. span; 5500 lb. no sleet.

Insulators:

Number, 190,000; 58 per cent of which are on dead ends.

Type, 2565-P Locke.

Diameter, 10 in.

Dry flash-over voltage........	590,000 suspension 720,000 anchor.	9 disks
Wet flash-over voltage........	420,000 suspension 420,000 plus anchor	

Routine Tests:

First test per disk, electrical, flash-over voltage.

Second " " " mechanical, flash-over voltage, 5000 lb., after first elec.

Third " " " electrical, flash-over voltage 5 min. after mechanical.

Ultimate tensile strength, 10,500 lb.

Maximum working tensile loading allowed, 4250 lb.

No. of disks used per chain, straight line, 9

" " " " " " dead end, 2 x 11 = 22.

Two chains are used in parallel on all dead ends to divide mechanical load.

Distance center to center of insulator, $5\frac{3}{4}$ in.

Two telephone circuits on an independent pole line 300 miles long.

Resistance per circuit 4000 ohms. Storage batteries used on transmitters, and power-driven machines for ringing.

Eleven patrol stations are necessary, each requiring an equipment of tools and material weighing 10 tons.

Presented at the Philadelphia Section meeting of the American Institute of Electrical Engineers, Philadelphia, Pa., November 10, 1913.

THE CLASSICAL-SCIENTIFIC VS. THE PURELY TECHNICAL UNIVERSITY COURSE FOR THE ELECTRICAL ENGINEER

BY ARTHUR J. ROWLAND

THE idea of a technical course for engineers is relatively new. Like most new things it has had to prove its merit in order to secure proper recognition. It received little sympathy in its beginnings, and even today, when education for definite vocations has won its long battle, many of the older men are apt to think that what was good enough for them, ought to be good enough for any one. The headway made by the technical course in recent years shows that it is here to stay; it has definite merit and a definite place in education. I do not undertake to say that the old-fashioned "arts course" has no merit or that it may not form a good foundation for an engineering course in cases where a man has time to pursue both branches of learning. One problem only is considered in this paper. Is the classical-scientific or the technical course the better for the engineering student? The subjects included in a technical course are those immediately connected with the application or expression of science.

Successful Courses Must Have Proper Character

A very important consideration when weighing the relative merits of the classical-scientific vs. the technical course is that which takes into account the elements which make for success.

The act of entering an engineering course and following it, is a purely voluntary act on the part of anyone. A sufficient incentive must then be found to draw students and hold them after they have started. If a course is to be successful, two things are paramount in securing the necessary results: the interest taken in the course, and the value of the reward which is to be secured on graduation.

The attitude of most people, especially in a country like our own, where there is no distinction of class or caste and where

many very humble homes are represented by students in college courses, is to question the value of all the subjects of instruction included in them. A man in one of our elementary evening classes asked, "Why should I go through all this here mathematics to learn a little about motors?" (He was getting decimals, percentage, and simple proportion). A father discussing a college not a thousand miles away where his son was at work, said to me, "It's a place where French and ancient literature form the bulk of the engineering course."

Interest is the element which can be best counted on to make a course successful. The interest of students who really care is held when they are doing the real things of applied science or are studying subjects which manifestly have some bearing on the career they had in mind when entering an institution. The interest taken by the general public in a particular engineering course is often set by the reputation in consulting or research work gained by a man at its head; or by the way in which he is able to keep in the public eye. Even though such a man has no ability as a teacher and habitually neglects his students, his course may be extremely successful for a while at least, merely because of the interest in the man which has been established with the public. But in the long run, it is the way in which engineering knowledge secured in a course of study fits the needs of the community, which counts the most. Every day people in the world are coming more and more to recognize that pure science has its relation to the real interests of the community only in so far as it supports and clarifies the applied science, which is the great community servant. The Cincinnati experiment in cooperative engineering has proved successful mainly on account of the recognition by the community of the value of the professional training given in it. It is surprising to see at how early an age the modern youth takes a definite, practical view of life. It may even be as far back as the first or second year of high school work.

The other incentive which causes men to hold on to the end of a course and graduate is the reward to be secured. This reward may take the form of the diploma or degree which is won; the kind of position which may be secured as the result of the efforts of many and well-organized alumni; the graduate's future standing in the world, gained as the result of the reputation of the institution with which he has been connected. Such rewards are to be given their due weight. A man's future may

be influenced as much by them as by any real knowledge he possesses. Such rewards may even make a course apparently successful in which the students really take no interest at all. And yet the best reward is certain to be the self-consciousness that as a graduate a man is trained to think and to work intelligently and efficiently. He is only so trained when he has within his command the tools of his profession along with a thorough knowledge of its principles.

Existing Engineering Courses All Have Some Special Characteristics

A large number of the existing engineering courses have been planned on the basis of certain State-established entrance requirements, using curricula developed from the old "arts" courses. They are arranged so that no engineering subject can be reached until calculus is finished, and since this is rarely earlier than the end of the sophomore year, the first part of the course is filled with general education subjects. People who are highly educated in general subjects, who are learned as the result of long culture environment, who know the art of fine writing, and the delights of poetry, approve such courses. Those who know nothing of engineering but have fixed ideas as to what constitutes college education are ready to help to frame them. But what do they mean to the boy who, with his heart set on engineering, never could make anything of the philological side of language or history? He falls out of the running before ever he gets a chance for even a taste of it.

There have been many places where the personal ideas of those who conduct engineering courses have been quite unable to influence very strongly the character of the work offered. Tradition and precedent count for too much. The engineering director of a course in such a place, who has originality and understands the importance of practical training, eventually succumbs to the inevitable.

That something is wrong in the characteristics of many engineering courses is pretty well shown by the lack of fundamental knowledge shown by college graduates who have been given places in the large electric manufacturing companies of the country. Some years ago a book of questions and answers was printed and offered for sale by a couple of men connected with one of these big companies to help student apprentices to required knowledge. I looked over a copy and eventually wrote

the authors to ask whether it was possible that graduates in engineering really were ignorant of the answers to most of the questions. The reply I received seemed to indicate it was so; a clear indication, I had to conclude, that practical training was sadly lacking in the courses they had followed.

Are Purely Technical Courses Really Successful?

Classical-scientific education leads to conditions like those encountered in the engineering department of a large corporation I visited some months ago. The chief engineer (himself a college man), in reply to a question, said, "I would rather have a man from the tool room in the designing work than any college man." After pointing out a number of men in the room from prominent colleges and universities, he said further, "All they know is how to design a beam to support a fixed load a given number of feet beyond a wall, or other purely textbook problems. How the beam is to be held in the wall, or the load suspended from it, is beyond them." It is a long slow process to train men who have never taken the steps passing from pure to applied science, to take hold of real live problems of the engineering world. They have the principles, perhaps, but do not know how to apply them. In the technical course the very same principles are presented, but would be coupled with applications such that the student comes to feel that they all have a vital, direct relation to practical affairs. The test of knowledge is the ability to think clearly on a new problem, rather than to search the filing cabinet of the brain for the data which show that the new problem is simply a variation of some old one.

In the classical-scientific course, research men may be developed; but too often such men are sadly lacking in the ability to handle practical problems, because of a narrowness of vision. Of course we must recognize, on the other hand, that in such courses, as in those of other non-engineering types, education, no matter in what direction, has a value of its own which all know and appreciate. Association with educated people, living in an environment of cultivation and learning, must produce an uplift, a broadening of view, which is fine to gain. There may be many men taking engineering courses who delight in language study as an art, in the broad reaches of modern and classic literature, and in the theories of pure science; but in this paper I am keeping in mind the kind of man who is an

engineer because he is destined to it, whose whole fiber is bound up with thoughts of design and construction. Such a man does not take such a course because he picked it by chance; or because he thought it might prove as interesting as any other. He takes it because there is no other which seems to him half so attractive, half so worth while.

The cultural value of certain kinds of studies is commonly urged when championing a classical-scientific course. Now culture is "to know the best that has been said and thought in the world." "The training, development, or strengthening of the powers, mental or physical, or the condition thus produced; improvement or refinement of mind, morals, or tastes; enlightenment or civilization." "Act of improving or developing by education, discipline, etc.; the training, disciplining, or refining of the moral and intellectual nature." On such bases there is as much culture to be found in technical subjects as in any other sort. Is the mind any less cultured which can appreciate a fine piece of reasoning and the direct engineering application, than the one which can appreciate a fine piece of music? Is the technical investigation of transformer theory any less cultural than the reasoning ability developed by logic or ethics? Are we not badly hampered in securing a clear feeling about such matters because of what we have been taught and the precedent of many years of established ideas? The sense in which the term culture is often used seems to indicate that a person who is cultured is for that reason able to shine in society; to talk well with strangers on subjects they know. It seems a pity that people generally cannot better appreciate scientific and engineering subjects. It is a pity if an engineer when he is in "society" must drop all reference to the subjects which command his interest in his daily life.

If securing culture includes gaining a first-rate mental development, I may suggest that, as too often taught, subjects like language and history and even some kinds of science and mathematics are memorizing subjects. It requires no special mental development to gain purely informational knowledge. Scientific and engineering subjects must be thought through and understood. There is no higher culture than the ability to think clearly and well. One who can do this should also be able to express himself clearly and well. I have wondered sometimes whether the so-called culture subjects of some engineering courses were not included as fillers, because to teach them only a class room

and a teacher are required and they are relatively inexpensive. Certainly a type of mind typical of the highest type of manhood can be acquired quite as easily through studying technical subjects as through studying Chaucer and medieval German.

Technical Courses Have Some Very Distinct Merits

The man whose life work is applied science sees and appreciates the direct application of everything he gets. The Cincinnati cooperative scheme in engineering education is a first-class illustration of this. The difference between the gain of a student whose alert and active interest is held by conscious applications as he reads his text or participates in class discussions, and that secured by the student who blindly grasps at principles and laws in an abstract way, is startling to one who has seen the difference. In our own engineering work the professor of chemistry has recently diverged from the old beaten path of general chemistry, qualitative analysis, etc., to engineering chemistry (really a much harder study). The difference in the class and its attitude toward the work were remarkable. The active interest, the feeling that they were now learning something worth while, were typical of the difference referred to above. The student in the technical course knows that he is being equipped with the tools of his profession. He feels that every hour of work takes him toward the goal he wants to reach. The teacher can count on the interest and attention of his class to such an extent that he may find them impatient at the speed he thinks it safe to make.

The whole trend of modern education is to train for usefulness. Relatively few are so well favored that it is possible for them to consider higher education merely as a wholesome broadening influence in their lives. Besides this, the immense field of knowledge which is included in engineering nowadays leads to the conclusion that if a reasonable idea of fundamental principles and a little of their application are secured within the length of time most people can afford to give to college, no subjects except those which are technical can be included.

Of the cultural side of a technical course much could be said. While studying engineering, the student gets in an incidental semi-conscious way a knowledge of the victories of peace, and of the magnificent achievements in industry. Such things are certainly of much more real value and more worth knowing about than the trend of things in the world as studied from the

standpoint of conquest and war. For there are heroes of engineering today. We find them in the men who are really doing things for their fellow men, making the sum of human happiness steadily greater. More and more we are coming to realize that the men who are bent upon destroying their fellow men and blocking real progress in the world by war or political intrigue are not the heroes for our youth to emulate.

The Technical Engineering Course Should Reach Back of College Work

It is but a short space of time since practical subjects taken in the period of school work preceding college entrance began to be counted in securing credits for entrance. Today they are too often discredited, both with reference to entrance and in securing recognition or credit in connection with freshman work. Standard college entrance requirements have forced high and college preparatory schools to a definite kind of training which in many cases does not admit of any engineering subject being studied even in an elementary way, until the college course has been begun. Many and many a parent looking forward from the grammar school period of education, anxious to have the boy trained for some sort of engineering pursuit, gives up the whole thing as hopeless when he finds that six years must pass (four of high school and two of college) before any real engineering subject is touched. There are very many boys between fourteen and sixteen years of age who leave school early in a high school course when they find there is no hope of securing training there in anything they consider practical, anything directly connected with industrial pursuits, wherein they hope eventually to secure their livelihood, their opportunities, and their advancement in life.

Manual training schools have to some extent tried to meet this difficulty, although originally devised purely for general education purposes to train the hand along with the mind and produce an education of the whole man. But they have often gone wrong, and the relation of their work, or rather a lack of relation, to the electrical industries is shown when it is found that, for example, in a large and successful one not far away, students are graduated without ever touching a circuit through which dynamo current flows, or looking through a telescope at the mirror of a reflecting galvanometer.

Conclusion

I believe heartily and sincerely in the technical course for engineering students. Whatever the advantages of others, it is my belief that none equals it in yielding rich incentive to scholarship, life interest in one's daily work, and definite hope of rewards to be gained. But I also believe that a far greater need could be met were it possible to start engineering education early in the high school period and distribute the general education subjects commonly found in that period, all the way along to the time of graduation from college.

Presented at the Philadelphia Section meeting of the American Institute of Electrical Engineers, Philadelphia, Pa., November 10, 1913.

THE CLASSICAL-SCIENTIFIC VS. THE PURELY TECHNICAL UNIVERSITY COURSE FOR THE ELECTRICAL ENGINEER

BY HOWARD MCCLENAHAN

THE range of thought embraced by this comprehensive subject is so great that only some few phases of it can be even mentioned here. I shall therefore restrict myself to the expression of views concerning the best possible method of training electrical engineers, of producing electrical engineers, who are at the same time thoroughly educated men of the world.

Aristotle has stated the purpose of education to be to make the best possible man out of any one individual, to make the individual the best man that he can be. The best possible man, I take it, is the man who contributes the best of life to those dependent upon him and to the community and the country in which he lives. The best possible man is the man who brings good judgment, broad learning, toleration, and good-will, as well as marked professional or business ability, into the affairs of his life. In a word, the best possible man—the best which any individual can make of himself—is the man whose every capability is brought to the highest degree of development of which it is capable.

From this point of view then, the point of view of total education in opposition to partial, fractional education, I wish to speak first this evening.

Validity of judgment is dependent upon ability to take into consideration every factor which can affect the matter under consideration; and such ability is dependent upon knowledge of all these factors, is dependent upon knowledge of the legal, the economic, the scientific, the human, the sanitary, and even the religious aspects of the matter. Judgments which are based upon partial knowledge are dangerous just because they are partial, because they fail to take account of factors which may make, or mar terribly, the success of the whole venture.

The best medical judgment is not that of the physician who

knows all that is to be known of medicines and their effects upon the human system. The best medical judgment is that of the physician who has full knowledge of his materia medica plus a knowledge of the social and ancestral and religious antecedents and environments of his patients.

Breadth of knowledge, upon which good judgment must rest, can be attained only by broad training. It can never be gotten through a purely technical training, thorough and fine and valuable as that may be. It can be had only by a study of history and economics, of philosophy and literature, of mathematics and the sciences. It is my own belief that nothing else contributes quite so much to the development of the imagination, of perseverance and of the power of logical reasoning, as well as a knowledge of the most important ancient civilizations, which have affected vitally present-day civilizations, as does the proper study of Latin and Greek. But whether or not other languages be substituted for these two classical tongues, it seems certain that wide knowledge can be obtained only by a wide range of serious study.

Complaint is constantly heard from the heads of large manufacturing concerns, from consulting engineers of international standing, and from those having the power of public appointment, of the almost insuperable difficulty of finding well trained, thoroughly developed men to take responsible positions. A limitless supply of half-trained engineers, of men who are technical men only, is constantly at hand. The supply of men who can do this one thing, or that one thing, well, is never exhausted. The number of men who can look at any problem broadly and inclusively, who can think and can form a valid judgment about any new project, is said to be almost vanishingly small. In no other profession is there more room for men at the top than there is in electrical engineering. This lack of well rounded, trained men is due to the necessary effect of technical training, for technical training, by its very nature, is narrowing and is not conducive to broadness of vision and broadness of judgment. In technical work, how much of success or failure depends upon painful attention to minute details? How many of us who have done experimental work in electricity have not risked our immortal souls when nothing would go right and profanity alone seemed satisfactory, only to find that all of our trouble was due to a loose contact in an inaccessible place? This necessary attention to detail has, and must have, the effect of developing narrowness rather than broadness, of limiting one's powers rather

than of developing them in every particular. Another unfortunate effect of such narrow, rigorous training, and technical training must be most rigorous if it is to be anything, is the production of the feeling, too often, that a thing must be useful in order to have any value, the production of an unwillingness to learn anything unless it can be shown that it is immediately, or almost immediately, applicable to some practical end. This feeling is, perhaps, not the necessary result of purely technical training. It is, however, so common among purely technically trained men as to warrant one in being almost convinced that it is a nearly inevitable result of such one-sided training.

I have attempted to indicate the necessity for a broad, general training for engineers when viewed from the side of rounded development and usefulness. I wish, however, now to attempt to show that even in those things which are called technical subjects, the best training for the engineer is the broadest training upon which is superposed the detailed, strict, technical training. Mathematics and physics and chemistry are not tools of the engineering profession. They are the very foundations of all engineering and their applications constitute engineering of all types, for engineering is simply, in every case, the application to the specific of the general principles of physics and chemistry and mathematics. Therefore, the man who has the best training in the fundamentals of these sciences and who has the greatest grasp of their principles, is, other things being equal, the one who will make the best trained engineer. The constant tendency in engineering training is to regard these sciences as the tools of engineering rather than as the very body and substance of engineering. In far too many cases, physics and chemistry are taught as "engineering physics" and "engineering chemistry," to the great loss of both engineering and the two sciences. For example, physics may be taught as the tool of engineering, in which case, the student receives instruction in only those portions of physics which the particular instructor thinks will be of use to the engineer, without overmuch regard to the fact that he may be omitting those portions which help to make physics a great constructive mental discipline. This not only injures a student's knowledge of physics and his conception of physics as a science, it must also produce in his mind an impression in favor of useful knowledge and a distaste for that which is apparently useless. This result necessarily handicaps the growing student in his subsequent work, for one can never predict when knowledge, which is ap-

parently useless, will become the most highly useful of all one's attainments. An example of the difference of these two types of training may be taken from any of the several branches of electrical science, from electrochemistry, from electrical designing, from illuminating engineering.' We have probably all seen the designer who can design, by the application of certain empirical rules, machinery which will work efficiently and satisfactorily, so long as those machines are of standard type, but who becomes puzzled and unable to modify his formula for application to machines of a radically different type. The illuminating engineer may be trained to lay out properly an equipment for the satisfactory illumination of buildings, yet whose understanding of his work, and his success at it, would be greatly heightened by full understanding of the principles of radiation and absorption of colors, and of physiology. Endless illustrations of this point could be offered to make clear what is meant, but perhaps so much as has been given will suffice.

The foregoing remarks indicate, I think, fully enough, what I should regard as the best method of training electrical engineers. It would consist of at least three, and preferably four, years of training in a general course leading to the degree of B. A. or B. S. In this course a student would study the great branches of human knowledge, literature, philosopny, economics, history, languages, physics, chemistry, and mathematics. He should study the principles of these subjects in order to get a grasp of each, and especially should he study physics as physics, and chemistry as chemistry, and not as tools for the engineering profession. And then there should be superposed upon this fundamental training a two-year rigorous technical course. By such training a student would be prepared thoroughly to carry on with maximum efficiency, and with maximum understanding and interest, the work of his professional school. He would come to his professional training with mature, trained mind, with a deep realization of the seriousness of his work, and with greater purpose to do it all to best advantage. He would take up the work as a trained man instead of as a growing boy. The experience of twenty years has convinced me thoroughly that this is the only method for training engineers most successfully.

Presented at the Philadelphia Section meeting of the American Institute of Electrical Engineers, Philadelphia, Pa., November 10, 1913.

SHOULD AN ELECTRICAL ENGINEER BE BROADLY EDUCATED?

BY R. H. FERNALD

BETWEEN the two titles given me for this brief paper, namely, " Classical-Scientific versus the Purely Technical University Course for the Electrical Engineer " and " Why an Electrical Engineer should be Broadly Educated," I have taken the liberty of naming a third as the heading for my remarks—"Should an Electrical Engineer Be Broadly Educated?"

The answer may, I believe, be readily given if the sphere of the electrical engineer be definitely fixed. The field which the electrical engineer occupies can best be determined by a review of that occupied by engineers as a class during the past few decades, as the electrical engineer's career has been influenced by well-established conditions which he found upon entering the field some twenty or twenty-five years ago.

Prior to the civil war the work of the engineer in this country was to a great extent that of the mechanic or artisan applying a trade. At that time civil engineering practically embraced all engineering work save that of the military engineer. Following the war the developments in transportation, manufacturing, power distribution, etc., accompanied by natural competition, created a demand for more thoroughly equipped engineers with specific training along scientific lines. This great demand for men of this type was met by the establishment of the Land Grant Colleges and technical institutions offering instruction in the specialized engineering branches demanded by the market of the day. The engineering graduate of the period was a well trained specialist but not necessarily a man of breadth of training.

The complexity of mere living has in the past twenty years increased at a tremendous pace and the time has now come when the question of meeting the normal demands of daily existence hinges in large measure upon the engineer—not the artisan alone nor the scientific specialist alone, but the engineer of large affairs controlling and directing the great agricultural, mining, manufacturing and transportation projects.

The electrical engineering profession, therefore, demands the services of the artisan, the technically trained man and the man of business initiative and capacity.

The trade school p'ays a peculiarly important role in training and educating men of the first class mentioned. Men of the second and third classes largely receive their education and fundamental training through the opportunities offered by the technical schools and universities.

Although in many instances the career of a young man in college may be carefully and wisely directed by his father or some interested friend, the trend of the majority of students undoubtedly depends largely upon the aims and personal ideals of the student, the direction and aid given by the professors and the element of chance common to all. Personality and intrinsic worth are in my estimation greater factors than education in determining real success. We all recognize that the closest application to business, even though it result in the highest efficiency, will not win desired opportunities for large responsibilities and coveted positions of power among men unless accompanied by a strong, pleasing personality, breadth of view, and cultural development. Let us consider for a moment the four essentials mentioned—technical efficiency, personality, breadth of view, and general culture.

The first, technical efficiency, may undoubtedly be acquired by the average student who faithfully pursues the engineering courses offered by the many technical schools and universities of the country and who consistently applies himself during a reasonable period following graduation.

The second quality, personality, is largely a matter of inborn characteristics beyond the control of the individual but which to a certain extent may be cultivated by association and environment. Incidental to environment is mental attitude, which is greatly influenced by the character of reading and study.

The third essential, breadth of view, has much to do in developing those qualities which fit a man to undertake big things. In exceptional cases only, is conspicuous breadth found in the product of the purely technical courses generally offered, and in these cases it is usually traceable to inherent qualities in the man or to unusual opportunities and associations after leaving college. The real foundation for breadth of view can best be laid during the formative period of the university student when his mind is readily responsive to suggestion. To me,

this seems the logical time for the introduction of that broader foundation upon which I believe every man can build much more securely and with greater assurance as to the future than when restricted by the narrower confines of purely technical training.

The fourth attribute, general culture, is largely a question of early environment, education and natural desire. Success, viewed from the financial standpoint alone, does not necessarily depend in any way upon culture; in fact, culture is often sadly lacking. Success in the larger sense—in the sense of greater attainments and the largest enjoyment of life—undoubtedly depends to a marked degree upon cultural development. The academic work of the university unquestionably offers the most direct educational foundation in this field.

The combination of the academic courses with the more utilitarian courses of the engineering departments opens the way to a larger sphere of usefulness, success, and enjoyment to the young man of capacity than the limited engineering courses. The broader and deeper the foundation thehigher the superimposed structure may be.

The purpose of a university course is effectively outlined by Dr. Washington Gladden as follows: "A course in a university has served its purpose if it has laid some good foundation on which future accumulations of experience may rest; if it has given some training in habits of investigation; if it has developed some power of appreciating the best in life and art; if it has laid down the lines on which study may be usefully continued; if it has lifted up and clarified some worthy ideals of conduct and service."

Two pertinent questions present themselves: first, what men take this broader university course, and second, what course should be recommended to a young man about to enter college?

My reply to the first query would be that there are two general classes of desirable students seeking an engineering education. The first class consists of those who have a definite inclination toward the mathematical and technical side but who have little interest in or taste for the literary and more general but less utilitarian work offered by the arts courses.

The second class consists of those who really desire a technical course as their professional foundation but who recognize the advantages of and have a taste for the broader and more general academic training.

Those of the first group naturally take the four-year engineering course, and in the second group there are always many

who for lack of time or funds cannot see their way clear to take advantage of the larger opportunities. Both types of course are therefore justified in a university.

The answer to the second question, viz., what course should be recommended to a young man about to enter college, depends to some extent upon the young man's financial condition. If financial considerations do not enter into the question, my reply would be that if a young man has reasonable capacity and is an all-around student of fair ability, I should by all means advise him to take a complete academic course leading to the degree of A. B. and then follow this by the professional course. Further than this I should prefer not to attempt, save in exceptional cases, to determine the exact professional course to be followed, until the young man is well established in his academic work and has had ample opportunity to familiarize himself with the details of such courses, to get in touch with the ideas of his associates, to discuss fully the future possibilities of the various fields and to readjust his own views and inclinations.

My remarks may be summarized as follows:

1. In electrical engineering, as in other engineering pursuits, there is need of three classes of men more or less broadly educated: the artisan, the straight engineer or technical specialist, and the all-around man of affairs and business capacity.

2. The educational institutions of the country offer opportunities designed to meet the requirements of each of the three groups mentioned, through the trade school and technical institute, the four-year engineering university course, and the broader academic course followed by the professional course.

3. Which of the two courses a man pursues at a university depends largely upon his early environment, caliber and taste, time and money at command, and, to some extent, upon the direction or suggestion received after reaching the university.

4. My closing thought is best expressed in the words of a professor of modern languages in a purely technical institution: "Society needs men who think quickly and accurately, who feel strongly and generously; men of sound judgment and catholic temper; men with a fine sense of personal and professional rectitude; men who, as Governor Hughes said, are to be 'trustees of the future of a great country.' Rare men are these, the product of native endowment, of home environment, of the education of school and of life. No institution may send forth a large percentage of such men, but every institution should try to."

DISCUSSION ON "SELF-CONTAINED PORTABLE ELECTRIC MINE LAMPS" (SWOBODA), PITTSBURGH, PA., APRIL 9, 1914. (SEE PROCEEDINGS FOR APRIL, 1914.)

(Subject to final revision for the Transactions)

H. H. Clark: The first requirements of portable electric lamps are safety, and the capacity for uninterrupted production of a sufficient amount of light. I wish to emphasize, however, that from the viewpoint of the mine operator, a lamp to be successful must be able to operate day after day with a reasonable amount of repairs and replacement. If this is to be accomplished the lamp battery must be a very sturdy affair. Failure of the battery plates will result in annoying delays and expensive repairs. A dependable battery is indispensable to satisfactory performance.

Another part of the equipment that is most important is the lamp bulb. The cost of replacing the lamp bulbs will be one of the largest items in the cost of maintenance. This cost will be in inverse proportion to the life of the bulb. So far as I have been able to learn, the manufacturers of miniature lamp bulbs have not in the past given much attention to developing the life of the bulb. Up to the present time the demand for battery lamp bulbs has arisen from the extensive use of dry battery flash lamps. The requirements of this class of service are apparently not the same as the requirements of the class of service that we are now discussing. At all events, the life that flash lamp bulbs give has not impressed me as being as long as the users of mine lamps have a right to expect. Reports from abroad lead us to believe that mine lamp bulbs in use there have a life of 500 to 1000 hours, and I presume that no American manufacturer would admit that he could not make as good bulbs as are produced in Europe. The question of bulb life was one of the first problems that the Bureau of Mines took up in connection with its investigation of portable electric mine lamps. The cooperation of bulb manufacturers was sought, and they are now undertaking to ascertain the requirements of mine lamp outfits for the purpose of producing longer lived bulbs.

Just now the electric cap lamp seems more in demand than the hand lamp for mine service. The cap lamp requires a flexible cord connection between the battery and the head-piece. The design of this cord and method of protecting it from abrasion where it is joined to the battery and to the head-piece is an interesting problem. So far as I am aware, we have no European precedent to guide us in designing this cord because cap lamps have not been developed abroad. I have no doubt, however, that as the result of experience in actual service, that part of the equipment will be developed satisfactorily.

The design of the head-pieces of cap lamps is a matter that should not be overlooked in specifying the requirements of mine lamps. It is important that head-pieces should be designed and constructed so that cord replacements can be readily

made. A most important feature in head-piece design is distribution of light. The light cast should be free from black spots and from sharply contrasting areas of bright and faint illumination, and it is especially desirable that the stream of light thrown out by the reflector should be so broad that shadows are barely discernible on either hand or on the roof or floor.

Mr. Swoboda's paper makes several references to candle power. I should like to ask him whether these figures refer to average candle power over the stream of light, or to measurements made otherwise, and whether with or without a reflector.

Mr. Swoboda mentions an average life of bulbs of 1000 hours. This is a most encouraging and significant statement, and I should be glad to have Mr. Swoboda tell us from what source this information was obtained.

H. H. Smith: It is gratifying to see that the storage battery miners' lamp is finding its place on the programs of technical meetings in this country. It appears from what Mr. Swoboda has said that in Europe they have advanced with the miners' lamp further than we have in America. He has also pointed out that the development has been along quite different lines. The portable lamp which contains the battery within its case offers quite a different problem from that of the lamp used as a head-piece with the battery separate.

I feel that it is necessary to take issue with Mr. Swoboda with reference to his attitude toward the alkaline battery for this class of service. On one of the slides shown on the screen, only a part of which is given in the paper, there was a table of operating costs in which you may have noticed that something over 20 per cent is charged to battery renewals and replacements, and about 35 per cent to attendance; or altogether more than half the cost of operating the lamps. The alkaline battery has advantages along these lines which I believe will tend to decrease these items of cost so as to more than compensate for the higher cost of lamp renewals claimed by Mr. Swoboda—as to the magnitude or importance of the difference in lamp life I am not at the present time prepared to say.

It is claimed in the paper that a battery life of 2000 shifts is of no value because the life of other parts of the lamp is less than that. Inasmuch as the battery is a distinct unit separable from the rest of the apparatus, it is not clear why full use cannot be made of its longer life, the value of which is important because the cost of the battery is approximately half the cost of the entire outfit.

In regard to maintenance, we all know how carefully a lead battery must be handled in order that it may not be overcharged or overdischarged. The charging board recommended for use with the alkaline battery is so arranged that no meter need be used in connection with it, no rheostat need be adjusted and batteries are simply slipped under a pair of spring contacts and

left there as long as desired. It makes no difference if it be left there longer than is necessary or for a shorter time than is required, so far as the life of the battery is concerned. Upon a battery being withdrawn from the board, a resistance is automatically substituted for the lamp, which is designed to maintain constant the current flowing through the circuit, so that a battery can be slipped beneath the spring contacts or withdrawn without any further attention to the board being required.

I have here a battery in its metal container which is designed to be strapped at the miner's waist in the ordinary manner. The cover of the container is secured by means of a hasp and locked with a padlock or, if desired, by means of a magnetic lock. The cord from the lamp is connected with the battery by means of a special plug which fits into a corresponding socket on the cover of the lamp container. When the plug is inserted it is automatically locked by means of a spring catch and it cannot be again removed until the cover is unlocked and opened and the catch released from beneath. The lamp remains lighted, of course, as long as it is in the miner's possession.

The safety devices are similar in effect to those which have been already described. The battery, to be sure, is made up of two cells, but inasmuch as there are only two cells and the containers are metal, the two adjoining poles that are connected together to throw the cells in series are grounded upon the cans and the cans are positively connected with one another, so that no insulation is required either between the cells or between the cells and the container. The battery, therefore, acts as a single unit and may be treated as such.

The cells are rendered unspillable by means of the special valve construction. The valve stem extends to the center of the cell, at which point it is open for the emission of gases. The normal level of electrolyte is below the center of the cell, and therefore, in no matter what position the cell is held, the end of the valve stem is never submerged.

The electric lamp is a boon to the miner and is likewise desirable from the standpoint of the mine operator. It is inevitable that its use will in time become universal. It is, therefore, our plain duty to ourselves and to all others concerned to work together for this end.

R. C. Burrows: In regard to the comparatively high voltage and slow drop in voltage during discharge of lead cells, I would like to call attention to the lead cell using a paste electrolyte. This type of cell does not have the slow voltage drop during discharge that is characteristic of the lead cell using a liquid electrolyte. This is due to the increased internal resistance of the cell with discharge. In the cell with which I have had experience, this increase in internal resistance is not very objectionable; in fact, the discharge characteristic curve lies about half way between that of the lead cell with a liquid electrolyte and the alkaline

cell. There is on the market at the present time a very cheap lead cell outfit using sawdust saturated with sulphuric acid as an electrolyte. This little battery, as far as I have gone with it, shows up very favorably as to discharge characteristics and, with its low renewal cost, should meet a demand where breakage is high.

As to advantages of the alkaline cell as outlined, the necessity of using two cells in series is not serious from the standpoint of increased weight and the life of the incandescent lamps might possibly be increased by discharging the battery through rheostats until the voltage reaches a fairly constant value.

Regarding the figure of 1000 hours life for incandescent lamps, it is a fact that a lamp may be made to live a thousand years, a thousand hours, or one hour, all depending upon the efficiency at which it is burned. The present tungsten lamps would live indefinitely if they were burned at an efficiency equal to the best operating efficiency obtainable for the old carbon lamp. The life of incandescent lamps, then, is dependent on the efficiency at which they are burned and the most economical efficiency must be determined from a consideration of all the factors involved, such as fixed charges, interest, depreciation, renewal of lamps, cost of energy, etc. In fact in practically every case with a tungsten lamp, the greatest economy of light production is obtained when they average 600 or 700 hours instead of 1000 or more hours, as is at present the practise. In determining the length of life of incandescent lamps with these small outfits, we must consider the total cost of the light production and the effect of the lamp efficiency on the weight and cost of the battery. The total cost of light production is not given a great deal of consideration as a rule, but it is nevertheless of importance in this case. These small batteries are only about 50 per cent efficient, so that the effect of decrease in lamp efficiency on the output of the battery should be multiplied by two in determining the most economical efficiency. The fixed charges are high, due to the rapid depreciation of the cell, interest on investment of the outfit and housing, attention necessary, cleaning, etc. If the life of the incandescent lamp had been determined at 1000 hours, considering the cost of incandescent lamp renewals and energy alone, then, the life of the lamp should be somewhat less than 1000 hours, taking into consideration the fixed charges. If the ratio of fixed charges to the cost of the incandescent lamp were eight to one, the most economical life would be about 300 hours, instead of a thousand hours as stated by Mr. Swoboda. In fact, this figure of three hundred hours was adopted by the Bureau of Mines in their proposed specifications. The ratio of eight to one does not seem to be particularly high. For instance, with the cost of lamp as 35 cents, the fixed charges would be $2.80 per thousand hours burning, or for about one-third of a year.

To increase the life of the lamp from 200 hours to 1000 hours

means approximately 40 per cent increase in the ampere-hour capacity, or from 30 to 40 per cent increase in the battery weight and cost.

I might add that in a case I have in mind, the Ceag lamps for the same total lumens weigh nearly twice as much as an American outfit which uses a lamp of high efficiency with a life of three hundred hours.

H. O. Swoboda: Answering Mr. Clark's question regarding candle power measured, this refers to the lamps *with* reflectors. I received this statement from the manufacturers of the Ceag lamp.

Regarding the life of the incandescent lamps, the same manufacturers make the claim of having had lamps burn one thousand hours. The same statement is also made by Mine Assessor Schorrig of the Prussian Government, in one of the papers which he delivered in Germany last year.

Regarding the alkaline battery, mentioned by Mr. Smith, I found that two cells are undesirable on account of the complicated connections. A single cell is much simpler in this respect. The alkaline battery is also more expensive, as far as first investment is concerned. This point has to be considered very much, because the lamps in actual service are destroyed very rapidly and have to be replaced very often. For instance, if the first investment should be doubled by using alkaline batteries, it would mean that the depreciation charges would have to be increased also one hundred per cent and that will counteract to some extent the advantages which are claimed from charging without instruments.

Regarding the electrolyte used in the lead battery not being a liquid, I wish to state that the electrolyte of this battery (Ceag) is a liquid. It is common dilute sulphuric acid, such as is used in any storage battery.

DISCUSSION ON "THE DEVELOPMENT OF THE ELECTRIC MINE LOCOMOTIVE" (EATON), PITTSBURGH, PA., APRIL 10, 1914. (SEE PROCEEDINGS FOR APRIL, 1914.)

(Subject to final revision for the Transactions.)

W. W. Miller: Referring to Mr. Eaton's paper, it may be of interest to note that a mine locomotive of 14,000 lb. weight with a single motor chain drive was built in 1886, and installed in the anthracite field. This locomotive was in daily operation until 1909, and although preserved since then for its associations and historical interest, it is still used in the mines whenever required by emergencies.

While the cast steel bar frame mentioned may permit a design of less weight to meet stresses applied in certain assumed directions, it is believed that the rolled plate frame is better adapted to withstand the abnormal and unforeseen stresses due to derailments, collisions, etc. Moreover, in all of the more usual sizes, *i.e.*, five to six tons for gathering, and ten tons or heavier for main entry service, weight is fixed by drawbar pull requirements and not by mechanical design, or, in other words, it is necessary to "ballast" the locomotive.

With the rolled plate frame, this ballasting is accomplished by increasing the power section, thereby maintaining the weight distribution over the axles and making the locomotive power so much the stronger and more stable. Ballasting by means of heavy cast iron bumpers, as is sometimes resorted to with the cast steel bar frame, has the disadvantage of causing unnecessary power stresses and giving a strong tendency to tilt, unless the wheel base is of more than the usual length. Also the integrity of metal in the rolled plate frame is believed to be superior to the best of castings. It might be well to state that some of the rolled steel frames I have seen are from five to six inches thick, and ballasted by means of heavy cast iron.

Because of limited clearances in haulage ways, it is desirable in the interests of safety first that a smooth unbroken surface, which cannot catch clothes or tools, and which does not allow trip riders or miners to ride on the side at the risk of life, should be presented by a passing locomotive. The rolled plate frame with all bolt heads, etc., countersunk fulfills this condition admirably.

While in some designs the openings of the cast steel bar frame may be utilized as hand holes, all main adjustments must still be made from above, consequently it would seem that the lessened protection to the equipment has not brought with it a compensating increase in accessibility.

The expression "frictionless" as applied to bearings of the ball type in contradistinction to the usual sleeve type, does not emphasize their most important characteristic. While experimental tests seem to indicate considerably better starting torque due to their use, and it would seem reasonable that their lower friction coefficient would save something in full speed operation, their most important quality is in maintaining the absolute integrity of the motor air gap.

Few people realize what a large proportion of armature and commutator troubles have their inception in bearing wear. With ball bearings in a properly designed housing, so that they are dust protected, and with even fair attention to lubrication, the wear is entirely negligible. Recent inspection of such bearings after 20,000 miles of locomotive operation, showed wear that could be measured only in the ten thousandths of an inch.

C. W. Beers: I am very much interested in Mr. Eaton's paper on electric mine locomotives, and as they are important factors in the production of coal, I would like to refer to some of the features which I consider to be essential to good locomotives.

As to the locomotive cover, it was originally made of wood, resting snugly on offsets in the side frames. In time these wooden covers would swell and cause trouble. A scheme that I have adopted with apparent benefit is similar to the cover shown in Fig. 2 of Mr. Eaton's paper, except that each cover piece extends over the side frames about two inches on each side. The cover plates are so supported on circular supports that they are about one and one-half inches above the side covers. This is a very good plan, as it gives free vent to the heat that is generated and permits the locomotive to cool more quickly.

I have found that the ordinary cover on the main journal bearings is not a satisfactory device for keeping out the grit, sand, etc., from the brasses, as in time this lid will not close properly, and hence the wash and sand from the locomotive will find an entrance. This causes a rapid wear of the brasses, and a tapering wear on the axle. To overcome this, I have adopted the plan of having this cover lid arranged to bolt fast to the bearing, and so far, I have found it to work out satisfactorily.

The old method of running the cables from the controller to the rheostat and motor was very unsatisfactory, as the cables would bunch on top of the motor and the vibration would damage the insulation. To overcome this feature, I have arranged on our later locomotives that cables coming from the controller should be placed in a built-up metal box, fastened to the inside top edge of the locomotive side frame, and from this main cable box the various cables would run straight out to the motor and rheostat. This makes a very satisfactory job, and keeps the top of the motors clear, as well as reducing cable troubles.

The old method of attaching cables to the rheostat by means of set screws was responsible for much trouble, as the screws would work loose or cut the cable and cause damage. We have overcome this trouble in our later type by using a clamping connection.

The brake reach rods in some of the locomotives pass over the top of one of the motors. This caused much annoyance when repairs were in order, as it meant dismantling part of the brake rigging. By having the reach rods pass along the side of the motor, this annoyance has been eliminated.

The arrangement of the foot pan is usually bad, because it

is usually bolted to the bottom of the side frame. This is shown in Figs. 8, 9, 10, 11 and 12 of Mr. Eaton's paper. Hence, when the locomotive rides over an obstruction, these bolts are liable to be torn out and the foot pan drops and may break the operator's legs. By fastening this foot pan to the iron ledges attached to the inside of the side frame, this danger is removed.

The ordinary covered and braided cables that are used for connecting the various parts of the locomotive to the equipment are not usually very successful, as the braiding soon separates and becomes fuzzy and in damp mines this is rather annoying. I think that cambric cables, with a hard, wear-resisting braid of good quality could be used to advantage.

In regard to circuit breakers; I prefer a circuit breaker if it is a good one. I do not believe, however, that the development of the locomotive circuit breaker has kept pace with the other parts of the equipment, and the circuit breakers furnished today on some makes of locomotives are very poor devices. The breaker should be stout to resist bumps, etc., it should be waterproof, and so arranged that it cannot be kept from operating by the use of the foot, sticks, wires, etc.

The development of the mine locomotive is a problem that cannot be put up entirely to the designing engineer. Rather should the experiment be brought about by the operating man, and by careful watching, many defects can be remedied, as I have found that the desiging engineer is usually very glad to co-operate with the operator. Many of these points which I have mentioned are the result of my observation and of conferences with these men.

The maintenance of the mine locomotive is largely a question of looking after details. Generally, the manufacturing companies handle the question in a very satisfactory manner, but it is usually the little things that happen in every-day operation that they are somewhat unprepared for, and it is here that the operating man could be of use.

For some years past I have endeavored to keep a record of locomotive costs. The costs to cover armature repairs, field coils, armature bearings, journal brasses, wheels, axles, gears and pinions, also brake shoes, controllers, rheostats, trolley poles, oil, grease, crabs, reels, sand, brushes, journal springs, etc. By getting these various costs for each colliery, curves can be plotted that will give a graphic comparison of the costs for each place, and by means of personal knowledge of the conditions at each place, due to long experience, it is usually an easy matter to take any colliery and point out the proximate reasons and causes for the high costs.

For instance, high rheostat costs, combined with high journal spring costs, indicate bad tracks, cross-overs, etc., and high brush costs and high bearing cost usually mean high armature costs; or, again, high wheel costs usually follow the sand curve, etc.

A close study of such a set of curves will indicate very closely what part of the locomotive needs redesigning to better advantage, or what internal conditions need attention.

From curves plotted in this manner, it would seem that the costs of armatures, bearings and brushes were closely allied. An investigation showed that bad armatures were usually caused by bad bearings. Naturally, if the bearings were bad the armature would not run true, and this caused commutator troubles which put the finishing touches to the armatures.

During the past year I have had thirty-nine armatures sent to the repair shop with old bearings attached, and instructions were forwarded to the repair department that as soon as an armature was received, its shaft should be trued up and the bearings babbitted to suit. Out of thirty-nine armatures thus sent out, only one was sent back for repairs. This appears to me to be investigation in the right direction, and also points out the fact that armature bearings can be further improved.

The brushes also came in for their share of experiment, and we find that massive pigtails are a distinct advantage. The pigtails ordinarily furnished are not particularly good. The pigtail should be so large that it shunts practically all the current from the brush holder to terminal, and thus relieves the brush holder of its electrical function as a conductor.

We are now conducting experiments with impregnated field coils, but up to the present time have nothing definite to report.

Referring again to locomotive costs, it may interest some to know the relative percentage of these costs. My experience indicates the following:

Armatures and bearings	16.60	per cent
Field coils	3.10	" "
Rear axle bearings	1.43	" "
Journal brasses	1.12	" "
Wheels and axles	14.90	" "
Pinions	0.75	" "
Gears	1.73	" "
Brake shoes	1.15	" "
Controllers	2.10	" "
Rheostats	1.24	" "
Trolley repairs	3.35	" "
Oil	1.29	" "
Grease	0.51	" "
Sand	6.13	" "
Brushes	0.72	" "
Journal springs	0.50	" "
Reels and crabs	3.00	" "
Miscellaneous material	16.46	" "
Labor	23.80	" "

It should be noted that this cost also includes warehouse material that has been purchased and charged out, although no use has been made of it up to the present time.

Probably the most frequent cause of locomotive trouble is due to bad bearings. When buying a new locomotive, we find that it will run from eight to fourteen months without much repair, after which time it is usually necessary to replace the wheels, and from this time on the repair costs are usually high.

In an endeavor to find out the cause of such increase, I have reasoned the matter out in this way: When new, the bearings and all parts have a good clean fit. After a time the use of sand is introduced, and this simply accelerates the wear, and soon the bearings are no longer good and considerable play is in evidence. Just about this time the gear and pinion show considerable wear, and begin to pound. This has a very bad effect on the armature and produces a bad effect on the commutation, and the armature is no longer central. Consequently the brushes get hot, the commutator blackens and the armature is then in line for repairs. After watching this performance a good many times, I have come to the conclusion that, since it is impossible to stop the use of sand, some form of bearing, both for rear axle and main journal, should be designed that is sand-proof. The armature bearings, of course, should be sand-proof, and in addition should be hard enough to stand the pounding of the gears, and both the sleeve type and ball bearing type appear to be improvements in the right direction.

During the past, our experience with gear wheels indicated that there was much to be desired concerning them, and from data that we have I find that gear costs follow closely the wheel and axle costs, and to my mind that indicates quick wear of gears and pinions and hence rapid wear of armature bearings due to the pounding of the gears. We are now trying out some extra hard gears and pinions, and expect to get better results.

Probably one reason for excessive gear and pinion wear is due to the fact that gear cases are not constructed to keep out dirt and grit. These find their way into the gear case grease and, of course, cause rapid wear. It occurs to me to ask if any one present has operated his locomotives without the lower half of the gear case.

In speaking of the reel or crab, Mr. Eaton says that locomotives equipped with this device cannot deliver empty cars to the face. This is not my experience, as I find in pitch regions that the crab can do this very well by means of a dead rope and a bull-wheel in the face, or by carrying the rope to the face. On the same page Mr. Eaton describes a clock spring reel. The idea is good, but it is very expensive to maintain, and I do not recommend its use.

Regarding the use of ball bearings, we have a few in use. They are good, and better than the babbitted shell. They are rather expensive to renew, but they do keep the armature in good shape. My experience has not extended over a sufficiently long period of time to state whether or not they are

better than the sleeve type, but almost any type is preferable to the babbitted shell, as these are usually soft and are easily pounded.

On account of the poor tracks which are encountered in the mine, it appears to me that grid resistance should be more flexible. A broken grid usually responsible for ultimate armature and controller trouble.

Carl J. E. Waxbom: With reference to the design of electric mine locomotives, we believe that some stress should be placed upon the "safety first" idea, and we found it absolutely necessary to adopt a type of frame which was unbreakable, and such a type of frame is found in the rolled plate or slab frame construction. We found that the use of cast frames, whether of steel or iron, has always resulted in some flaws being found in the castings, and this experience, I believe, will be borne out by everybody. Therefore, I think that the rolled plate frame has overcome that objection.

With reference to ball bearings versus sleeve type bearings, I think that the ball bearings have a decided advantage, inasmuch as they lessen the cost of operation and upkeep of the locomotive, particularly that of the armature. This cost, I have found in some cases amounts to as high as 80 per cent of the total cost of the upkeep. We applied some ball bearings some six years ago, and they are still running without any wear. I have also found users of mine locomotives who have expended, for a year's service of 16 locomotives, only $10 for the cost of lubrication. These locomotives, as I recollect, have been in service for over two years, and after a periodical examination of the ball bearings there was no perceptible wear on them.

The most important point in our opinion is that in the design of ball bearing housings case should be taken so as to preclude any foreign material getting into them, and with that design I would say that the ball bearing, with proper lubrication, should last indefinitely, or just as long as any other part of the locomotive.

With reference to the frame construction, I believe that the rolled plate type of frame should be recommended, even in case of the largest type of mine locomotives. I think that safety should be the first consideration in the design of mine locomotives, and I think that it is entirely met by the plate type frame construction, which, as one speaker stated, runs up to as high as six inches in thickness.

Graham Bright: I do not believe that the illustrations show nearly all of the advantages that are obtained in the open steel bar type of frame. The question has just been brought up in regard to the safety of this type of frame, in that men are liable to jump on the locomotive, and may slip and have their toes cut off. I have talked to several mine operators who are using this type of locomotive, in regard to this point, and they seem to think, while it might possibly occur in some mines, there are

probably only one or two openings where this could possibly happen, and they were willing if absolutely necessary to close those openings up with small plates and get the advantage of the other openings for inspection and ventilation.

There is no doubt in the case of the box type frame that, due to the heat losses of the motors and resistances, the temperature must get pretty high inside the box, there being practically no ventilation, and since the capacity of the locomotive depends on the continuous rating of the motors, (not the hourly rating,) for all day's service, there is no doubt that this continuous rating must be considerably increased by the ventilation obtained by the open steel bar frame.

Mr. Eaton states that with the single motor and side rod, you are not able to obtain a series parallel combination of the motors. I mentioned yesterday in discussing Mr. Reed's paper that I thought this was more fancied than real, because in most cases you will find the motorman will not use the series combination on the controller. In the parallel position it gives a little easier start and he does not have to worry about changing the position of the reverse lever if he wants higher speed, and the result is that he seldom uses the series position. Unless we can obtain a series parallel type, like a railway controller, that is low enough to be used for gathering service, I do not think there is much in the series-parallel combination, from a power economy standpoint.

Mr. Eaton calls the ball bearings "frictionless" bearings. Some tests have been made on a motor, with both ball bearings and with the sleeve type of bearings, in order to determine the difference. At very low speeds there is no question that the ball bearing has considerably less friction, but at medium and high speeds the difference is scarcely noticeable. In fact, some tests show that more friction is obtained with the ball bearing than with the sleeve type of bearing. Unless a ball bearing is properly lubricated and protected from dust it will very quickly give trouble and when repairs are required they will prove very much more expensive than with the sleeve type.

When the first mine locomotives were brought out, the motors as a rule did not have sufficient capacity for the service to which they were put. The result was that the electrical repairs were very high. There seems to be lately a swinging toward the other direction, and many operators and some consulting engineers are insisting on capacities which are really far in excess of what is necessary to perform a given service. The result is that the electrical repairs go down, but, on the other hand, the mechanical repairs mount very rapidly. The reason why these mechanical repairs are not so evident is that when the electrical trouble takes place as a rule you have no warning until the trouble actually occurs, there being no indication of what is going to happen. In the case of mechanical repairs, they can always be foreseen far enough ahead to have

repairs made without delay to the service. The result is that these high mechanical repairs are really not made manifest, but I think you will find where a locomotive is very much "over-motored" that the low electrical repairs are brought about at the expense of high mechanical repairs.

F. L. Stone: There has been a great deal said about the increased ventilation and the beneficial effect of the open side locomotives as compared with the box frame. I would ask if any concrete tests have been made to substantiate the claim? Personally, I do not think it amounts to anything, because the box locomotive is open both top and bottom, and the fact that the sides are closed does not, I believe make any material difference.

G. M. Eaton: While I have no definite comparative tests of mining locomotives with solid and bar frames in exact conditions of service, I would call attention to the fact that in testing a motor in the shop, if one inadvertently leaves the window open, perhaps ten feet away from the motor, on a day that is moderately cool, there is a very great difference in the results that are secured. Personally, I have no doubt that if the motor can run in free and open air, that is cool, it increases the capacity of the machine.

L. J. Ilsley: In regard to locomotives being "over-motored" or "under-motored," in my experience with several different types of locomotives, it seems that the average motorman is inclined to haul just about all the locomotive will haul; it is the same old question—if he had a mule that would pull three cars, he would attempt to pull four cars with it. If he could easily haul four cars with a locomotive, he would try to haul six cars. I have known of this problem being met by reducing the gear ratio, and by using heavier motors, so that the motorman can only haul a certain load, and, therefore, not overheat his armature and his field coils. This is harder on the wheels and the brake shoes, but I think, on the whole, it is a saving to the mine operator.

In regard to the cable reel which is operated by a motor, and reels out against the torque of the motor, I had experience with a different type of reel which works on the same principle, and this reel seems to work very well, except in cases where the trolley voltage was very poor. In the earlier types of locomotives there was a tendency in the controller design to make the terminal posts so small that one could get only a portion of the lead wires in them; one had to cut them down in assembling the wires. I am glad to see that in the later designs they have made ample room for putting in the leads both in the rheostats and in the controllers.

The question of the design of a mine locomotive should, in my opinion, receive special attention with regard to making repairs on the locomotive, for the average mine is not usually equipped with the best advantages and facilities for making

repairs. In the railroad shop you have your jacks and everything you require to handle the locomotive, but in the mine you may have a small pit out at some distant portion of the mine where you make your repairs, and, therefore, the locomotive should be designed to assist the repair man in every way, in changing armatures, wheels, and bearings. My experience in the maintenance of locomotives has shown that a great many of the troubles due to armature and field coil burnouts are due to lack of inspection of the equipment.

W. W. Miller: I think the usual tests made on the motors Mr. Bright mentioned, with ball and sleeve bearings, are made with the same motor, with the same air gap. We have found after considerable experiment, that you can use a much smaller air gap with a ball bearing motor. This means an increase in efficiency, with a resultant saving in kilowatts consumed. Recent tests on a considerable number of motors of various manufacturers indicated such material discrepancies in the service capacity of the motors having the same ordinary rating, that it would seem any slight advantage in external ventilation is entirely negligible, compared with the inherent electrical design and loss distribution of motors.

F. L. Stone: Mr. Eaton's reply to my question in regard to the actual heating tests on locomotives with open frames having been made is only a partial answer. I agree with Mr. Eaton, that a motor would run cooler in a sealed room with one window open than it would with the window closed, but I question if the motor was in a room with five windows and four of them open, whether the opening of the fifth window would make any material difference in the temperature rise of the motor.

W. A. Thomas: Some mention has been made as to the cost of production of various types of frames. Admittedly, a defective casting in the foundry does increase the cost of the cast steel frame. The structural shapes and plates we know, from market prices, can be purchased in a varying market from $1\frac{1}{4}$ to $1\frac{3}{4}$ cents per pound, and if any of you have had occasion to buy steel castings you found they cost quite a bit more per unit of weight.

Mr. Miller brought out an important point with reference to the use of ball bearings, that the easier starting is undoubtedly true with the ball bearing, because it is a point contact, and is, as Mr. Eaton brought out, somewhat frictionless For that reason it is my judgment that there is a decided field for the ball bearing, especially in gathering work, which is made up of starting and stopping much of the time; but in the main haulage work, the use of ball bearings and that of the sleeve bearings has not had, relatively, enough trial to determine their respective merits, although one large operator, who tried locomotives of different design and of different manufacture, and all with the ball bearings, with the best design of housing obtainable, has stated that the advantages of the ball bearings which

they had hoped for, had not been obtained, and therefore in their later locomotives they were resorting to the oil waste packed sleeve bearing. That is only one case under one set of very severe conditions.

The contention that there is no wear in the ball bearing is theoretical. Experiments have shown that there is wear. Resorting to smaller air gaps to get more power out of a given weight has resulted in offsetting the main advantages of the ball bearing by the armature going down in the tail pieces on comparatively slight wear.

Another point which Mr. Beers brought out is an important one with reference to the use of babbitted bearings, babbitt metal being subject to hammering from poor alignment of gears. This applies again because, as I think the last speaker brought out, you cannot get proper inspection of the equipment under various conditions of installation, and you get a very heavy hammering of the bearings due to the condition into which the gears wear. This, in some cases is breaking the ball bearings and causing replacements, and in some cases the bearings will last only six months, being comparatively expensive to maintain.

It is extremely difficult, as Mr. Beers pointed out, to keep the sand out of any bearing. This is, perhaps, more important in the case of ball bearings than in the case of the sleeve bearing, because with the latter full of oil, the sand, if it gets into the bronze brushing has a tendency to be carried out, whereas with the point contact there is a constant grinding, due to the fact that no attempt is made to keep a flow of oil through the bearings.

As regards the matter of safety, this appears to be largely theoretical, as is indicated by a recent order which the manufacturers have had for a bar type construction, in which order they have been requested to put in step plates in the end openings of the frame for the trip rider to get on.

The question of motor capacity should, perhaps be, qualified. Increased motor capacity obtained by speed has no advantage, because you have no greater tractive effort, relatively; and consequently—while the bare statement of power would appear advantageous—the speeds go beyond the practical limit, and the fact that you can only accelerate a certain train with a given tractive effort removes the advantage of the increased power. As a matter of fact, it is thought by some, and that thought has merit, that the question of the tractive effort in terms of the one-hour capacity of the motor, as laid down by the Standards Committee of the American Institute of Electrical Engineers, should be the prime consideration of the relation between the electrical capacity and the weight of mechanical equipment.

It is interesting to note in connection with the discussion of the gathering proposition, that as far as we are able to determine, and from my personal observation, the storage battery was the first type of gathering locomotive tried out. That

represented, of course, a battery of fifteen years ago, which was tried out at the Pocahontas Collieries at that time, and the electrician, after burning out several suits of clothes with acid, devised what was known as the "Wampus." The motors were hung outside in order to put the battery in the center. That left a relative short wheel base, with a clear field underneath the battery, so that when the battery was removed he took an old electrical wire reel, with wooden flanges on it, and put a shaft through it, and wound his cable up on this old reel. Then he mounted on the end of this shaft a large wooden disk, and on that end of the shaft he made an arrangement so that it would raise and lower the bearing support on the shaft, resting this disk on the wheels of the locomotive, and hoisting it off when he did not want to wind the cable. That was, so far as I know, the original gathering locomotive, and is interesting in connection with the general development of the locomotives.

I agree with one speaker in regard to the question of terminals. A great improvement has been made on the controller terminals, and I think further improvement can be made in increasing the size of the terminals and the method of attaching the same in the resistances. Mr. Beers made some statements on that particular point. Personally, I advocate either a terminal soldered on to the end of the cable, or else a sleeve soldered to the end of the cable.

As to the question of air-gap, I mentioned before that the relative dangers due to the bearing going down are modified to some extent in the ball-bearing motor by reducing the air gap, and unquestionably this removes, to a great extent, the claimed advantages of the integrity of the air gap, if you do not keep the same air gap as is used with the sleeve bearing.

G. H. Shapter: Mention has been made of the storage battery locomotive as a future possibility in overcoming certain difficulties encountered in gathering work. It is true that quite a number of such machines have been installed. Some of these have been more successful than others, and for the most part the few failures noted have not been due to the locomotives or batteries, but rather to conditions existing in certain mines, such as flimsy tracks, lack of sufficient ties or spikes to properly hold the weight of the locomotive and prevent the rails from spreading, curves improperly laid, etc.

In one instance I had occasion to note a track laid $\frac{3}{8}$ inch narrow, and as a natural result the locomotive was off track for an average of two hours per day. Now, to prove my point that conditions will be the obstacle that must be remedied, I will say that on the very next installation of a storage battery locomotive no trouble of the slightest character was experienced with derailment. The storage battery, in common with all other locomotives must be provided with suitable rails in order to make their speed and increase the output.

Storage battery locomotives of a certain manufacturer are now operating successfully in coal mines, and range in capacity

from 500 lb. drawbar pull to 2400 lb., and speeds of $3\frac{1}{2}$ to 5 miles per hour. The height varies from 27 in. to 46 in., and the width from gage plus 6 in. to gage plus 16 or 18 in., depending on whether inside or outside frames are used.

A careful study of the cost of operation, maintenance, repairs, power and attendance, etc., show that a saving of from 30 to 35 per cent can be effected by the use of a storage battery gathering locomotives as compared to mules. The calculations have been extended to a period of ten years and can be verified by actual results obtained in practise over a period of two years. The approximate estimated cost is four cents per ton mile.

The segregated value of various items considered in the cost of operation of these storage battery locomotives is as follows:

	Alkaline	Lead
Interest on investment....	3.7 per cent	3.2 per cent
Depreciation and renewals of battery.............	9.0 " "	11.5 " "
Depreciation of locomotive	6.5 " "	11.5 " "
Battery incidentals.......	0.8 " "	0.85 " "
Electrolyte renewals......	1.0 " "	0.00 " "
Locomotive repairs, oil, etc.	2.0 " "	2.15 " "
Motorman and helper.....	65.0 " "	70.00 " "
Power for charging.......	11.5 " "	5.40 " "
Total.................	100.00 per cent	100.00 per cent

The relative value of the two totals are in the proportion of 94 per cent to 100 per cent, showing a very close margin. Cost of power does not enter greatly into the case even when figured at two cents per kw.-hr., and for most isolated plants this extra power may be obtained during periods of light load on the generator without extra costs.

Personally, I do not believe storage battery locomotives can be as yet considered on an equal efficiency basis with trolley locomotives, perhaps never will be, but most certainly they will prove better than mules or some form of cable devices.

Apprehension may be felt on the score of durability and strength of the battery. I have seen cases with both the acid and the alkaline battery where the battery has been compelled to deliver power for pulling the locomotive onto the track after a severe derailment, which they did without any apparent bad results. The heavy current drawn under such conditions can well be imagined when I say it was necessary to hold the current breaker in by the foot.

C. J. E. Waxbom: I want to call your attention to a point with reference to the ball bearings, which I believe has not been brought out as yet, and that is there is no wear to take place on the armature shaft with the use of ball bearings, and I think that is an important point.

E. H. Martindale: It has been pointed out in the discussion on this paper that a great deal of trouble is encountered on electric mine locomotives due to worn bearings. It has also been

pointed out that a large percentage of the commutation trouble can be traced to the unequal air gaps caused by the low bearings. It is rather surprising to note in this connection that the slotting of commutators, that is, undercutting the mica from between the copper bars of commutators on electric mine locomotives, has not gained headway more rapidly. At the present time I do not think that more than 10 per cent of the electric mine locomotive motors are operated with slotted commutators, while on street and interurban motors probably 95 per cent of the commutators are slotted.

With the recent legislation in some districts compelling the mine owners to pay miners on the run-of-mine basis, it will be necessary for the operating department to cut down expenses wherever possible, if the mine owners are to continue to operate their mines profitably.

The slight saving in brush cost by the use of slotted commutators is of practically no consideration, the great reduction in cost being accomplished by the saving in commutation wear, reduction of flash-overs, and burned out armatures, and other commutation troubles. With an unslotted commutator on such severe service as the average electric mine locomotive motor, it is necessary to use a brush which has sufficient abrasive material to grind down high mica which is caused by the sparking, which occurs under the severe conditions. This necessarily means a brush which is continually grinding the commutator, and the cost of a new commutator for a motor is usually more than the cost of the brushes that will be used on the motor for ten years.

The slotted commutators will permit the use of a high conductivity, low friction, non-abrasive brush, and the sparking which will be caused by unfavorable conditions, such as the worn bearings will not have the serious effect upon the commutator and will show a very great reduction in maintenance charges With slotted commutators, however, it will be necessary to have careful inspection at regular intervals to prevent coal dust, carbon dust or other foreign materials from collecting in the slots and causing short circuits.

N. W. Storer: There is one point brought out that I feel I am able to discuss, and that is in regard to the efficiency and ventilation of the motor. One gentlemen made the statement that ball bearings enabled the air gap to be greatly reduced in the motor—that is probably true, from a mechanical standpoint; and if it were desirable to use the minimum air gap possible with mechanical clearances, every motor would be built with that minimum air gap; that is, the minimum air gap for the particular type of bearing in use. Such is not the case, as every one knows. One motor may have one-eighth inch clearance, another one-quarter, or five-sixteenths, or three-eighths inch—it depends on the electrical characteristics that are to be obtained with the motor. It is not simply a matter of efficiency, either, in reducing air gaps. I think in a great many cases you increase the effi-

ciency of the machine by increasing the air gap. When a motor has an extremely small air gap, it is liable to have far more losses induced in the pole faces than it would have with a larger air gap and corresponding increase in the turns on the field, necessary to overcome the larger air gap. It is a case of having the air gap to get the commutating characteristics that you want, as a general rule, not simply to get sufficient space for the armature to turn in.

Now, in regard to ventilation; it is perfectly true, what Mr. Stone has said, that one window out of five makes little difference on the motor, but there is no question at all about the fact that a motor under a box even though it may be wide open underneath and have small openings on top, is going to run a great deal hotter than one which has holes on the sides as well as the bottom and top. We know from experience that a railway equipment, with a motor well surrounded by the truck, will run a great deal hotter than one which is more exposed, in fact, that a motor that is on the head end of a truck will run cooler than the one on the rear end of a truck. That has been tested out time and again. There may be 10 or 15 deg. difference in temperature between the motors on the same truck, depending on the location, whether leading or trailing.

G. M. Eaton: Mr. Beers asked a question about split versus solid gears. The split gear is at best only a makeshift, though often it seems unavoidable. If the operator has a small shop with no press, it is tremendously tempting to apply a split gear. It is easy to renew, and has to be renewed. As everybody who uses them knows, there are more or less troubles with the split gears. I say that, representing a company which sells a great many split gears. The company with which I am connected always recommends the use of solid gears, where possible.

With regard to the use of hard gears, they are surely coming in mine locomotive work. The use of the split gear has until recently made the use of a soft gear essential.

It is only recently that hardened split gears have been used, but they are now produced commercially by various manufacturers. They are expensive, but they make up for the increased cost by their long life.

Mr. Beers also called attention to the need of co-operation between the users and builders of electrical machinery. He struck the keynote of development. The more of such co-operation, the better.

"Safety first" is of vital importance. I regret that the discussion of this principle has been all from the side of the manufacturers, because although the manufacturers keep in the field, to a certain extent, they do not live day and night with the machines. The real proof of the safety of a given type of machine is its actual performance, and this record must come from the operator. Safety first must be observed, not only from the standpoint of the designer, but from the standpoint of the education of the men in the mine, that, as far as possible, the men

must be made to realize where their lives are in danger. This is true, regardless of the apparatus used.

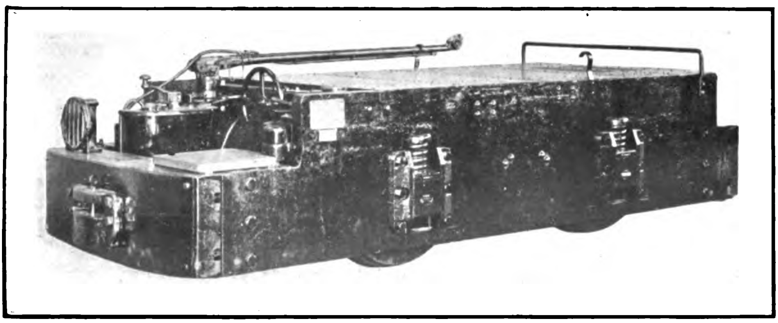
The storage battery locomotive which requires tracks better than those found by experience to be practicable and commercial, is doomed to failure. The storage battery locomotive must be adapted to existing conditions.

F. L. Stone (by letter): The question of open frame versus closed rolled steel plated I think is worthy of a little further discussion. In the first place, the mine locomotive of the future will be as indestructible as it is possible to make it. It must be able to withstand severe collisions and frequent derailments without injury. The open frame locomotive Mr. Eaton advises had its inception in the main line railway locomotive. This type of large locomotive is built for high speeds and is not designed to withstand collisions or derailments. There are many other stresses which they have to withstand, which do not necessarily enter into the design of the mine locomotive. Steel castings of the shape shown are at best of questionable strength due to shrinkage stresses. I note Mr. Eaton says the frame can be repaired with comparative ease by either electric welding or by the thermit process. I do not know just how much significance to attach to this statement.

In regard to the stability and strength please contrast Figs. 8 and 18 with the rolled plate side frame shown herewith. I believe it is impossible to construct a locomotive that will withstand the severe conditions of mine service, better than the rolled plate side frame locomotive. There are possibly some slight advantages to be gained by the open frame when it comes to renewing brake shoes, etc., but I do not believe Mr. Eaton would recommend the abandoning of the locomotive pit even though nothing but open side frame locomotives were installed in the mine.

The question of miners riding while standing on the frames should be further emphasized. Mr. Eaton advises that if they do ride they are liable to lose their toes, or be hurt against the mine rib. They will surely ride if there is a place for them to stand on and in all probaility will get hurt.

In regard to the cooling due to the open frame it is not fair to contrast the mine locomotive with the high-speed railway locomotive, or to draw conclusions from one and apply them to the other. I have seen many schemes of ventiliation fail, notwithstanding the fact that they look perfect on paper. When tests have been made and, evidently they have not as yet, I would be pleased to hear the results. Finally, a locomotive of a given draw bar pull must have a weight in proportion thereto. There cannot be a better place to put this weight than in the side frames. If it is placed outside the wheel base the tendency is to make a "rocker", which is very liable to leave the track should there by any unevennes sin the roadway. I have seen this rocking so bad that it was almost unsafe to run the locomotive.



TEN-TON ROLLED-STEEL SIDE-FRAME LOCOMOTIVE [STONE

DISCUSSION ON "MINE DUTY CONTROLLERS" (REED), PITTSBURGH, PA., APRIL 9, 1914. (SEE PROCEEDINGS FOR APRIL, 1914.)

(Subject to final revision for the Transactions.)

F. L. Stone: There is one line of control on which Mr. Reed has touched very lightly. That is the handling of 2200 volts. This voltage is coming more in use every day, and must be controlled in a safe and efficient manner. The use of oil-immersed switches was the first method tried, but where the operation is frequent and the service severe, as in the case of the mine hoist, either of the slope or shaft type, it does not work out as well as might be hoped. The frequent rupturing of the arc carbonizes the oil, and will eventually cause an arc-over. This comes without any warning to the operator, and usually puts the switch out of commission. Another cause of damage to oil-immersed switches when operated frequently is, that a body of gas will form on top of the oil and finally a hot bubble will arise, and if the proper proportions of air are present a violent explosion will occur, this frequently wr.cking the tank, and putting the switch out of commission until repairs can be made. The ordinary oil switch such as used on a switchboard for control of various circuits may be called upon to operate two or three times a day. A switch to control a hoist operating two trips a minute will operate approximately 1000 times a day in eight hours. In the first case the oil-immersed switch is entirely satisfactory, while in the latter case such information as I have been able to gather seems to indicate that it is entirely unsatisfactory.

The only alternative seems to be a properly designed air-break contactor. Such contactors have been designed, and are on the market, and from everything I can learn are giving satisfactory service. Two of these air-break contactors were installed about one and one-half years ago at the Crow's Nest mine of the Keystone Coal & Coke Company, controlling the primary circuit of a slope hoist of 700 h.p. The operation has been continuous since installation, and even the arcing tips have not as yet been renewed. I have a letter from South America, advising that the air-break contactors are giving most excellent service. One contactor in particular installed at one of the mines was put in service early in March, 1912, and at the end of two hundred and forty-four days of operation it had opened the circuit 388,000 times without any renewals or repairs and at a maintenance cost of nil. On the other hand, reports from the same locality on oil-immersed contactors advise that, on account of danger of fire when the oil becomes too much carbonized it must be renewed every four or five weeks, and between 30 and 40 gallons of oil per switch are required.

From these figures you can readily appreciate that the maintenance of such a switch is a very expensive luxury.

All of the above only applies to switches which are required to operate on a rapid cycle.

Mr. Reed refers to an encased moisture-proof starter to be used in gaseous parts of the mines. I believe it would be better if this casing were built on the principle of the safety lamp, rather than attempt to make it air-tight. Any device of this sort is bound to breathe, that is to say, expel a certain amount of air when warm, and draw in air from the outside when cold. If this action is carried on long enough the quality of the air inside of the box will be the same as that outside, and an explosion might readily be started. Or, when the box is opened for inspection, it will, of course, fill with air from the outside, which may be an explosive mixture. I believe it is generally conceded that it is almost impossible to make a perfectly air-tight joint through which electric wires can be brought. I would like to have an expression of opinion from the Bureau of Mines on this subject.

Mr. Reed in his article makes no detailed reference to control of motors by liquid rheostats. The general trend of the practise seems to be that in motors over 500 h.p. a liquid rheostat should be used for the secondary control. The up-keep of such rheostats should be considerably less than the up-keep of the large contactor panels. The freedom from steps is a very important consideration, and is obtained only in the liquid rheostat. It has been a very difficult problem to design a liquid rheostat with a large ratio of resistance without having the plates so close together that the danger of arcing in event of the motor being reversed is more excessive. This, however, has been accomplished by the use of what virtually amounts to two chambers, one of them of high resistance and the other of low resistance. The low-resistance section is only connected across the slip rings after the motor has attained a considerable speed, and therefore its voltage across collector rings is low. The low-resistance section is cut in by means of a float switch. With such an arrangement the motor could be reversed without any danger of arc-over, as nothing but the high-resistance plates would be in circuit.

Finally, in regard to the part of Mr. Reed's paper referring to mine hoist control, it would seem as though Mr. Reed was of the opinion that a flywheel motor-generator set was extremely efficient. Efficiency is not the aim of the flywheel set, and it should only be used where excessive peaks are penalized or where power station capacity is limited, and it then must be realized that the running of a heavy flywheel throughout the entire day must be done at a considerable expenditure of energy. As a matter of fact, speaking generally, it takes about one and one-half horse-power per ton to operate a flywheel. I will be interested to hear from Mr. Reed as to why he differentiates between shaft hoisting and slope hoisting on the efficiency basis. Personally, I see no difference whatever, except that the control of the shaft hoist is a little more difficult than the control of the slope hoist.

Mr. Reed's statement that the electrification of mine shaft

hoists is of questionable economic value cannot be passed unnoticed. Mr. Reed, of course, would not make such a statement unless he had some figures based on tests and actual observations to back it up. Being particularly interested in mine hoisting, I would deem it a great favor if Mr. Reed would advise us as to just how he arrived at the conclusion that the electrification of mine shaft hoists is of questionable economic value. I have yet to see the case where the shaft hoist has been electrified that it is of questionable economic value.

Sidney G. Vigo: I would like to inquire of Mr. Reed what, in his opinion, is a fair estimate of the largest capacity alternating-current motor that can be applied to a hoist and operated directly on the line of a central station without causing undue disturbance on the system, after taking into consideration the application of the proper controller, as discussed in the paper. This is largely determined, of course, by the size of the station feeding the system, but reference is made particularly to the smaller station, say of 2000 kw., carrying a diversified load. We have had considerable trouble with some of the smaller stations in several instances, by operating motors of 150 horse power directly on the line, using magnetic control. In these cases, faulty regulation of the lighting load was evident.

Graham Bright: High continuity of operation of any apparatus can only be obtained by a constant and systematic inspection. This is particularly true of mine work, since the conditions under which its apparatus has to operate are so very bad and it is difficult to get a good class of operators and inspectors, due to the poor living conditions and isolation of the average mine.

For small pumps up to 20 h.p., the self-starting motor is the best solution of the control problem, as it eliminates the control entirely. If too many motors of this type are placed on a system the first rush of current may prove too much for the generating system, in which case a relay could be provided on some of the motors which would delay their starting for a few seconds so that all motors would not start at once. It seems that the self-starting motor would be a better solution of the problem than the usual control as shown in Figs. 1 and 2. However, where a company has already installed motors that are not of the self-starting type, this control, of course, would be a considerable improvement over the present method of having to cut in and start by hand.

Mr. Reed states that the series and parallel drum controller with the series and parallel feature in the reverse drum is advantageous because it is easier to get straight series only, during gathering. I believe that the straight series position is seldom used, as the motorman will invariably start in multiple. It gives him an easier start, and he can generally start larger loads, since one pair of wheels slipping does not increase the tractive effort of the other pair as would be the case with the motors in series. The real reason for making the series and parallel arrangement on

the reverse drum is on account of the limitation in height. The regular railway type of series parallel controller is too high for mine service, due to the series parallel feature being in the main drum. It has been my experience around the mines that there are few motormen who use the series position very much. The railway type of controller would be a distinct advantage in that the motorman must start in series every time.

I wish to take issue with Mr. Reed regarding his statement that almost invariably the straight vertical type of hoist can be best electrified by the use of the variable-voltage system and that with this arrangement in many cases electrification is of questionable value. It will be found in practise that in a large majority of cases an a-c. wound-rotor induction motor will be used for vertical hoists and will prove the most economical, not only on the basis of first cost but also on cost of operation. Very rapid hoisting, with few or no delays, coupled with restrictions regarding the peak loads that the power company will permit on its system, will only warrant a flywheel equalizer system with voltage control. For very rapid hoisting it is sometimes desirable to use the voltage control system on account of the superiority of the control itself, which readily lends itself to the addition of automatic features. In case the power system can stand the short-time peak loads it is not necessary to use a flywheel, and a synchronous motor-generator set can be used to supply power to the hoist motor. The flywheel and slip regulator losses will be saved and the first cost will be considerably less.

There are no doubt a few isolated cases when it will not pay to electrify a steam-driven hoist, but in the majority of cases a very substantial saving can be made. There are steam hoists in West Virginia at which the cost is over five cents per ton for hoisting from not over 400 feet in depth. Some of these hoists will be electrified in the near future, and it is expected to cut the cost of hoisting to less than one-half of what it is at present.

H. H. Clark: Mr. Stone has asked for a comparison of the explosion-proof qualities of oil switches. The tests that the Bureau of Mines has made have been rather limited in number and have been confined to switches of relatively small capacity. No tests have been made with controllers. The tests were made at 250 volts and with currents no greater than 100 amperes. I have not in mind the exact conditions that surround these tests, but about 75,000 breaks were made on each switch while it was surrounded with the most explosive mixture of Pittsburgh natural gas and air. No ignition took place during the tests and it seems reasonable to believe that all switches can be made explosion-proof if the parts are properly proportioned to the service to be taken care of and if the presence of the proper amount of oil in the switch casing can be assured.

From the tests that we have made I can not say what would happen to an oil controller that is being operated a great many times a minute. It may be that in a comparatively short time the oil level would fall to such an extent that the flash of breaking

the circuit might be exposed and in that case gas would certainly be ignited if it were present. I can say this, however, that in almost every case that we tried it was necessary to renew the contacts several times before the oil level fell to such an extent that the breaking flash was exposed.

H. D. James: Mr. Reed, in the beginning of his paper, makes the following statement:

"Only within the past few years have those concerned realized that the selection of a proper controller is as important as the selection of a suitable motor."

I wish to emphasize this point, as I can recall many personal experiences in which the selection of the motor was such that it was almost impossible to furnish a satisfactory controller. A motor may embody the ideal features for the particular application, but render it very difficult to control this motor in a satisfactory manner. This point has received the attention of both motor and controller engineers with increasingly satisfactory results.

A still further development of the situation has produced the engineer who has the training and experience necessary to study the customer's requirements and select both a motor and controller which will give the best economical results, apart from a purely scientific consideration. This man is commonly known as an application engineer. It is necessary for him to analyze the design characteristics of both the motor and control, and collect the necessary data showing the conditions of load and method of operation that give the best results for the customer. Often the motor can be modified slightly in design, and the controller changed to give a larger output with less strain to the apparatus and decreased power consumption. This is very important from the standpoint of the customer, as the only two items which usually interest him, are first, the amount of capital invested in the apparatus, and second, the cost of power and maintenance.

He is not willing, as a rule, to pay for new and interesting scientific experiments. Occasionally such features have an advertising value, but as a rule, they have no commercial importance. The man who spends most of his time following the design of either motor or control is not usually equipped to make a well balanced application. The electrical industry owes a great deal to the pioneer application engineers, and it is profiting more every year by the increased number of these engineers who are making a special study of each customer's requirements and assisting the customer to solve his power problem so as to get economical operation and increased output.

W. C. Kennedy: In many of these cases, particularly the ones referring to the mine hoists, the equipments are developments, not of the controller alone, but it is a question of the adaptation of the controller, the hoisting machine, and the motor to the conditions of service—a great deal like the ordinary electric-driven elevator. You have to make all three units work together. Sometimes you have to modify the controller

to meet the characteristics of the motor, and sometimes the motor must be modified to meet the characteristics of the controller, and local conditions also affect these different items.

The controller shown in Fig. 1 has been referred to as unsafe for installation in the mine. That controller was discussed under the head of "Fan Motor Control." That is not designed, primarily, to go inside the mine, where it would be subject to explosive gases. In nearly all cases the ventilator fans are mounted at the top, outside, and at the head of the shaft. The main feature of these fans is continuity of service, and to be able to get any speed adjustment desired over a wide range. The amount of air to be delivered varies greatly, depending upon the weather conditions. That controller is designed for use with the shunt-wound motor, having a speed range of about 4 to 1. It is capable of being set to any predetermined point and locked in that position by the mine operator.

The controller shown in Fig. 2 is also not of the enclosed type. It is not so elaborate as the first one, because it is not designed for adjustable-speed motors. It is intended to be used with drainage pumps. These pumps, as I understand it, are located at a point in the mine which is determined by the main operating conditions. They are not usually located down where the cutting is going on, but are mostly on a ventilated shaft, where they obtain the best drainage, and then are connected to the different sumps or drainage wells.

We have built controllers using both air-break switches and the oil-immersed switches, and both types are in satisfactory operation.

The controller shown in Fig. 3 is of the air-break type, tightly enclosed, and I believe operates satisfactorily. We have made some controllers that are not closed as tightly as that, and personally I would be inclined to think this type of control would be better than trying to adapt the principle of the safety lamp. It may be argued that it may collect gas inside, that it is bound to breathe, which is true, but at the same time any electrical device must be inspected, or at least should be inspected, no matter if it is enclosed. There should be a man in every mine, as there is a man in nearly every mill, an inspector, whose duty it is to examine these automatic devices, but I think it would take a long time before that controller could collect an explosive mixture in it.

Mr. Clark has referred to his tests on the oil-break switches, and states that he has tried them up to 75,000 times, and they are still satisfactory. Of course, the ordinary switch will have to operate more than that. We have been very successful with oil-break direct-current apparatus as well as alternating-current apparatus, in situations where there is danger of explosions. This refers to a line of work which is not concerned with mining apparatus, and that is in the powder mill industry. It requires a great number of manually operated controllers, oil-immersed, and they are certainly in a dangerous position

when it comes to the danger of a flash or an explosion, and the only answer I can give is that both types of apparatus are operating satisfactorily.

In regard to the locomotive controllers, I am inclined to believe we would consider series parallel probably better than having the series on one side of the off position and parallel on the other. I think the point which Mr. Reed intended to convey was that we are building both types. Both of these special controllers are not the result of the conceptions and ideas of the designers, but have been cases where we have been called upon to furnish special apparatus, and I know that that drum controller was built at the request of some customer. I think that only goes to show that it would be to the advantage of every one concerned, both the manufacturers and the users, if the mine apparatus could be standardized and made to cover the general requirements, and kept away from these special things as far as possible. That has been done in the Pittsburgh territory among the steel mills, and I know that both manufacturer and user are benefited.

C. J. E. Waxbom: Mr. Reed has mentioned controllers for coal cutting machines. This is a type of apparatus which is subjected to much abuse in mines. The coal cutting machines start and stop very often, sometimes under heavy overload, and Mr. Clark suggested the use of oil switches for such starters. Personally I do not believe that oil switches for coal cutting machines would be practicable, as I am afraid that the carbonizing effect of the oil would be too much. Secondly, I believe that the men around the mine would put in any kind of oil which they found handy.

In order to better the starting apparatus for coal cutting machines, we have lately devised means whereby a coal cutting machine is started only once during its operation and then stopped. This is accomplished by means of friction control. The motor is started absolutely under no-load and can be released under no-load. In propelling the coal cutting machine from place to place, the operator of the machine does not operate the starting box, simply the friction control. In my opinion, that contrivance is one of the simplest and most effective, and I believe one of the most durable, of which we know today. It does away with stopping and starting of the controller, which has been the bugbear of many electricians around the mine.

W. M. Hoen: For fan motor control, alternating-current, a wound-secondary motor is advisable if starting current must be limited. If any great amount of speed reduction is required, and resistance control is used, the loss in resistance is objectionable, but, due to the character of the fan load, this loss will be much less than if the motor were driving a constant torque load. However, its use would be advisable where speed reduction was of rare occurrence.

A squirrel cage motor and its control is the simplest, and as possibly one speed for the majority of mechanical appliances

in mine operation is generally sufficient, a two-speed winding will give good results. The control apparatus can be made simple and the starting characteristics for either speed are suitable for fan operation.

Direct current is usually supplied because of locomotives, and if fan service is supplied from the same source, a separate feeder should be run from the busbars. This would eliminate the greater voltage fluctuation.

If direct current is used for pumping, the majority of the machines will be small, and the proper solution of the control apparatus is to eliminate it and use self-starting motors. They are available in sizes up to 20 h.p. and may be thrown directly across the line.

As to hoist control, drum controllers have been used to a great extent in the past, but with increasing use of magnetic contactors, their increased reliability make it desirable to use drum controllers only on small, low-voltage hoist motors where the service is intermittent. Except in shafts of very large output and extremely fast work, the induction motor is applicable and can be controlled by contactors when the motors are of average size, and a liquid rheostat can generally be used for the larger motors. This liquid rheostat is very simple, consisting of a number of plates connected to the secondary of the motor, and supported in the upper section in a two-compartment tank. The liquid is a carbonate of soda solution and is kept in constant circulation from the lower to the upper tank by a small centrifugal pump. The level of the liquid in the upper tank compartment which contains the plates, is lowered or raised by means of a hollow weir which is under the hoistman's control. This type has the advantage of simplicity and minimum maintenance.

The voltage control system, as described, is ideal, and is only required where the loads to be hoisted are large, the rope speeds high, and the acceleration and retardation rates very fast. If power conditions limit the permissible peak, a flywheel set with induction motor and liquid regulator as described in paper is proper. If the peaks are not a limiting feature, a synchronous motor-generator set will give all the desirable control features, somewhat decreasing the first cost and the no-load running losses.

Coal cutters were formerly built only for use with direct current, but are now available with induction motors. These can be thrown directly on the line, permitting the use of a single oil switch.

A mine with large power requirements can dispense with direct current except for locomotive operation. This simplifies the control problems and permits oil switches to be used for all control work.

Arthur S. Biesecker: Under " Pump Motor Control," in the last sentence of the first statement is the following: " The starter should be designed for automatic acceleration of the

pump on resumption after failure of line voltage." That, to my mind, is rather a broad statement. I am not very familiar with the bituminous field, but in the anthracite field a very large part of the pumping is now done with centrifugal pumps. If that statement is put in practise, I am afraid that the result would be very unsatisfactory to the operator. If you put an automatic starter of that character on a centrifugal pump, and the power goes off, you lose the water, and then your automatic starter brings your motor up to speed,your runners will run hot, and stick, and then you are in trouble. To my mind that is rather a broad statement.

There are several places around the mines similar to that, where it would be positively dangerous to put on an automatic starter, and the only thing to do when the power goes off, is to let the pump stand still until the pump runner comes back and let him start up the pump again, and see that the conditions are right for starting.

W. C. Kennedy: In regard to the last remark, I think that local conditions would alter that to some extent. I have seen one installation in which a controller, practically of that same nature, was used. It was so arranged that in case the voltage fell below any predetermined point to which it was adjusted the starting resistance was cut back in the circuit, and if the voltage rose again it would automatically accelerate. It was also provided with a feature of control so that, in case of failure of voltage, it would start up again in case power was applied. This controller is in operation, and I have seen the installation at intervals of two or three months, and so far as I know it is all right, but there may be some conditions that would alter that. That pump draws from a sump well about three or four feet below the level of the pump. It pumps against a pressure, I believe, of 20 lb. There is one check valve on the suction line, and I do not believe there is any on the delivery line. So far as the controller manufacturer is concerned, he can make the controller so that it will start up again on the application of power, or not, one way just as easy as another.

The question of acceleration has not been spoken of very much. As usual, there are two types of acceleration, one that is not under the control of the current, and the second is the current-limit acceleration using either series switches or shunt switches with relays. The first is usually known as the constant-time acceleration. We manufacture both types, and under the wide fluctuations of energy which are usually found in mines, we find that the constant-time-element acceleration gives much better results, because the current-limit acceleration is found to give trouble, especially if it is necessary to accelerate a heavy load, with varying voltage, or in case of a variable load. In that case it is practically impossible to use the current-limit acceleration. However, I believe that the voltage condition in mines will gradually improve and that may vary the design of the starters considerably.

Discussion on "Motor-Generator Sets vs. Synchronous Converters in Mine Substations" (Hoen), and "Mine Substations; Their Construction and Operation" (Booker), Pittsburgh, Pa., April 10, 1914. (See Proceedings for April, 1914.)

(Subject to final revision for the Transactions.)

W. A. Thomas: Unquestionably from the standpoint of economy the synchronous converter is superior to the motor-generator set, but in a careful analysis of the mining conditions, and the ultimate results to be accomplished, the question of the kilowatt-hours per ton in transformed energy constitutes a relatively small proportion of the total cost. The method of distribution of the direct current which has been converted has a great bearing on this question. As pointed out in Mr. Hoen's paper, the energy in the small mine is carried through one opening which is the main entry, and when the bituminous mine, particularly, as distinguished from the anthracite mine, comes to the commercial condition requiring electric haulage, the power is mainly consumed some distance from the entry. The distance of the point of consumption from the mine entry in the average bituminous field is probably upwards of a mile.

This gives rise to the necessity of over-compounding in order to maintain a fairly constant voltage at the point of consumption, and even at that it is not practicable to put in a distribution of copper in the mine to maintain much less than 10 per cent variation in voltage at the point of consumption.

It is for this reason that the motor-generator set is undoubtedly more popular in mining work than the synchronous converter, and this is particularly true of the bituminous mines, where large areas are worked out due to the thinness of the coal. There is, however, a field for the synchronous converter where several openings are served from one station, in which case a flat voltage is desirable. The question of efficiency of the converter over the motor-generator set is offset, to some extent, by the introduction of the over-compounding, so that at maximum load the losses due to the 10 per cent higher voltage transmission are less than on the flat compounding with the corresponding load on the station.

A particular point of advantage in the synchronous motor-generator set as brought out by Mr. Hoen is the power factor correction, and in this connection there is an interesting development which I think is followed by practically all manufacturers at the present time, and particularly in the low-voltage motor-generator set, of exciting the synchronous motors from the over-compounded generator, so that the field adjustment of the synchronous motor is made for good power factor at light load, and the 10 per cent over-compounding of the generator compensates for the increased load on the synchronous motor by bringing up its field excitation. That is being given study, and the suggestion has been made that in the use of 500- to 600-volt sets where a separate exciter is necessary similar results

can be obtained by one of two methods, either to put a series winding, auxiliary to the shunt winding, on the field of the exciter, the current in which shall be proportional to the load on the direct-current generator, so that in a similar manner the exciter voltage is brought up with the load on the set; or, another, and perhaps a more advantageous way of doing this is to excite the field of the exciter from the generator so as to get the benefit of the over-compounding by raising the excitation on the shunt field of the exciter. This would prove to be advantageous, doubtless, in railway work, as well as where the loads are greatly fluctuating, and where it would not, perhaps, be advantageous to run the excitation of the synchronous motor at maximum at all loads.

P. M. Lincoln: I have always felt pretty strongly about this matter of synchronous converters as compared with motor-generators where the problem is simply one of transposing alternating current into direct current. I have always felt that the synchronous converter had so many advantages over the motor-generator that there was no question about it. There are certain disadvantages, of course, connected with the synchronous converter when it is used. One of these disadvantages is that it is impossible to give it a high over-compounding, and if over-compounding is essential to the use of direct current in mines, that simply means that the synchronous converter is not available.

While I am rather familiar with the apparatus used, yet I will have to confess I am not at all familiar with the actual conditions that exist in mines, and so I am unable to express an opinion on the necessity of this very high over-compounding, which seems to be the general reason for demanding motor-generators rather than synchronous converters for mining work. The only thing that makes the motor-generator more applicable and better adapted to that duty is, as I said before, the necessity for that high over-compounding. If you can get away from the necessity for high over-compounding, I do not think there is any question, in general, that the synchronous converter will be much better for the purpose of getting the direct-current supply than any other piece of apparatus.

N. Stahl: Much of the emphasis of the superiority of motor-generator sets to synchronous converters for mine operation is laid on the over-compounding feature. As Mr. Lincoln has pointed out, it is undesirable, but not impossible, to over-compound the synchronous converter, even for cases where the rise only amounts to 10 per cent at full load. The difficulty arises from the fact that so large an amount of reactance is required; so that practically it leaves an undesirable feature on account of the excessive currents which flow in the tap coils of the converter at high load when you have a considerable amount of leading power factor current. The advantage, however, of the higher voltage procurable by the over-compounding of the motor-

generator can largely be eliminated by the very simple device of operating your converter at as high a flat-compounding voltage as you will get at the full load condition on the over-compounded generator. Inquiry develops the fact that both the synchronous converters, now standard for mine work, and the motors standard for mine work, are applicable for this higher voltage condition under light load, so that excessive bucking or flashing or commutation trouble is not to be expected. That being the case, the argument in respect to the average voltage on the direct-current line is in favor of synchronous converters, which permits a comparison more or less on the basis of the curves presented in Mr. Hoen's paper, which show, for a load, on the average, of three-quarters full load, about 7.5 per cent advantage in favor of synchronous converters, plus transformers, over the synchronous motor, running without transformers; but, bear in mind that in many cases transformers will also be required with the motor-generator, which will make the discrepancy still greater in favor of the synchronous converter.

If you evaluate for a particular case of an average synchronous converter substation capacity of 200 kw., on the basis of three hundred working days of ten hours each, and a load factor of 25 per cent—which presumably might be much better, particularly if advantage is taken of the present tendencies in design to construct machines which will carry safely 200 per cent overload for such length of time as is necessary for the accelerating of trains—you will find, on a one cent per kw-hr. basis, there will be a difference in cost of power per year of about $160, which represents about $6\frac{2}{3}$ per cent of the presumptive first cost of substation equipment which, by Mr. Hoen's figures, are placed at about a parity, with a tendency, however, towards an initial cost preference in favor of the converter and transformers, over the motor-generator alone, as the capacity increases.

The question of the power factor correction by the two devices has been raised. Mr. Thomas brought up the point that by the automatic over-compounding of the excitation of the synchronous motor directly from the generator or otherwise, through an exciter—which, by the way, increases the cost of the motor-generator set—much of the inherent automatic tendency of the converter toward a movement of the power factor through lagging values, at no-load, toward leading values at high load, may be secured on the motor-generator. To that no exception can be taken, so far as it goes. There is, however, an inherent tendency on the part of the operating man not to over-excite his machine, regardless of his instructions; that is, if his machine is operating on the basis of 80 per cent leading power factor at full load, the tendency is to get it as close to unity as possible, and let it stay there, or else under-excite the machine, on the mistaken notion that over-excitation

would force the field too hard, thus making the system power factor worse instead of better.

While there is no question of the ability of the synchronous motor, properly handled, to effect better conditions at the power house, taking them as they are under present conditions, yet the integrated values for the ordinary set will show, I think, a predominating influence in favor of the synchronous converter.

W. A. Thomas: From a theoretical standpoint, the contention of Mr. Stahl is absolutely correct, but when we take into account the fact that the connected apparatus on a substation ranges from 50 to 180 per cent over the capacity of the substation, and the fact that the average load factor of such a substation is about 35 per cent of its capacity, we have a condition in which with constant voltage, motors which are attached to that line are subjected to an over-voltage. In other words, if we take the voltage which is now practically standard in coal mining service, namely, 275 volts in one class, and 600 volts in the other class, we find the apparatus, the commercial motors, for pump driving, fan driving, and for cutting machines, ranged from 210 to 250 volts. The industrial motor, so-called, for driving pumps and fans, is standard at 230 volts. It is true you can get motors wound to 250 and 275 volts, on their fields, but it means ordering these motors specially, as no standard of this character has been established which is carried in stock.

In the buying of a pump, for instance, the proposition is taken up with a pump manufacturer, and he buys a motor from the local stock of the manufacturer with the result that he gets a standard motor of 230 volts in the low-voltage class, or 500 volts in the medium-voltage class. The result is that when he has a flat voltage of 275 or 500 volts and when the load is light on the station, he will get the full voltage of the circuit on his motor field. This is also true of the night cutting of coal, where the load is relatively small, unless an adjustment is made of the voltage at the power station with a flat compounding system. That adjustment, in the case of a converter substation, requires either a regulator or a shifting of the voltage taps applied to the synchronous converters. It is for these reasons, mainly, that in the installation of substations the use of the motor-generator predominates.

N. Stahl: There is one point in connection with the converter substations which should be mentioned. The use of synchronous converter substations in mines necessitates the use of two banks of transformers, in the event of the power being fed in at higher voltage than 2200. One bank would be necessary for feeding the local mine circuit and the other bank for feeding the synchronous converters. That adds to the first cost.

Will M. Hoen: From personal experience in metal mines, where the conditions are better than in coal mines, I think an underground substation, particularly in a coal mine, should always be avoided if possible.

In regard to motor-generator sets and synchronous conver-

ters, the intention was merely to show that the electrical work being done in mines nowadays is better than it was a few years ago. Formerly one generator was put in the mine entrance, copper was stretched through the mine, and things gradually grew on to the system. Nowadays, in the better class of mines, with the use of substations, their location and the distributing system can be advantageously planned; so that the question of using excessively over-compounded voltages should become of less interest. It undoubtedly is true that the majority of the substations have motor-generator sets, and use over-compounded voltages. This requirement is generally necessary on account of locomotives which require direct-current. Although a large amount of copper may be installed, the track circuit is in bad condition, and this generally accounts for the large voltage variations.

REPORT OF THE LIBRARY COMMITTEE

For Year Ending April 30, 1914

Board of Directors, American Institute of Electrical Engineers:

Gentlemen:—In accordance with Section 24 of the by-laws of the Institute, the Library Committee begs leave to submit herewith its report for the fiscal year ending April 30, 1914, showing the general condition of the library, and including the names of all donors to it.

The administration of the library's affairs by the Library Board, which was organized for this purpose with the approval of the founder societies in February 1913, has proved very satisfactory, and the Board has accomplished a considerable amount of constructive work during the year.

One of the most important matters to claim the attention of the Board was the general question of financing the library. The subject was brought up for discussion at a meeting held on December 4, 1913, and resulted in the appointment of a special committee consisting of the secretaries of the three founder societies to formulate a plan for the apportionment of expenditures and appropriations for the library, and to make specific recommendations for the classification of library accounts.

This committee submitted its report to the Library Board on February 5, 1914, and on March 26, 1914, the plan recommended by the committee was formally adopted by the Board of Trustees of the United Engineering Society. The principal features of the plan are as follows:

1. That a permanent Finance Committee of three members of the Library Board, one representative from each society, be created, each member being designated by the Library Committee of the society which he represents. This committee to have supervision of the library expenditures under the direction of the Library Board.

2. That the United Engineering Society bear one-quarter of the operating expenses of the library, dating from January 1, 1914, the remaining three-quarters to be borne equally by the three founder societies.

3. That all purchases of books, periodicals and binding be made by the librarian upon the authorization of the Library Committee of the founder society concerned, or in the case of the United Engineering Society, by the Finance Committee of the Library Board, and that the cost of such books, periodicals and binding be borne in each case by the society concerned.

4. That the research work carried on under the direction of the librarian be made, as far as possible, self-supporting.

Under this plan the United Engineering Society shares in the operating expenses of the library, which heretofore were borne entirely by the three founder societies.

The library now contains over 54,000 volumes, and about 1,600 com-

plete and partial sets of periodicals. Over 800 periodicals are received currently.

Data, which shall form the basis of a list of the sets of technical periodicals in the various libraries of New York City, have been obtained and the work of compiling this list is now progressing.

The research department has developed considerably during the year. Over a thousand questions have been received requiring research, and a large number of photographic reproductions and reference lists have been sent to out-of-town clients, both here and abroad, thus extending the facilities of the library to every part of the world. The fees for research work have been slightly increased, with a view to making this department self-supporting.

Statistical information concerning the library and its use during the year, including a list of donors, is given in the following tables.

DONORS

May 1, 1913—April 30, 1914

ADAMS, E. D	6
AMERICAN ELECTRIC RAILWAY ASSOCIATION	14
AMERICAN ELECTROCHEMICAL SOCIETY	3
AMERICAN INSTITUTE OF CONSULTING ENGINEERS	1
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS	1
AMERICAN MINING CONGRESS	1
AMERICAN RAILWAY ASSOCIATION	1
AMERICAN SCHOOL OF CORRESPONDENCE	2
AMERICAN TELEPHONE AND TELEGRAPH COMPANY	4
ARGENTINE SOCIAL MUSEUM	1
ARNOLD, B. J	6
ASSOCIATION OF IRON AND STEEL ELECTRICAL ENGINEERS	1
BARBIERI, M	1
BISHOP, L. W	1
BRAMMER, J. C	1
BROOKLYN ENGINEERS CLUB	1
CALDWELL, EDWARD	2
CARNEGIE LIBRARY OF PITTSBURGH	1
CHICAGO COMMITTEE ON GAS, OIL AND ELECTRIC LIGHT	1
CITY AND GUILDS ENGINEERING COLLEGE	1
CLEVELAND ENGINEERING SOCIETY	1
CONGRESO CIENTIFICO (1° PAN AMERICANO)	2
CONGRESSO INTERNAZIONALE DELLE APPLICAZION ELETTRICHE	1
CROCKER, FRANCIS B	5
DELAWARE COLLEGE	1
DEPARTMENT OF TERRESTRIAL MAGNETISM	1
ELECTRIC RAILWAY JOURNAL	1
ELECTRICAL WORLD	1
ELECTRO-TECHNICAL LABORATORY, TOKYO	2
ELECTRO-TECHNICAL LABORATORY, DEPT. OF COMMUNICATION, TOKYO	2
ENGINEERS' CLUB OF PHILADELPHIA	1
FORD, BACON & DAVIS	1

FOWLE, F. F	2
FOWLER, C. P	1
FRANKLIN INSTITUTE	1
GENERAL RAILWAY SIGNAL COMPANY	1
GAUTHIER-VILLARS	2
HAMMER, WILLIAM J	1
HERMANN ET FILS	2
HUTCHINSON, F. L	1
ILLUMINATING ENGINEERING SOCIETY	1
INSURANCE SOCIETY OF NEW YORK	1
IOWA ENGINEERING SOCIETY	1
JANECKE	1
JONES, R. M	1
JOSEPH DIXON CRUCIBLE COMPANY	1
KANSAS ENGINEERING SOCIETY	1
KENNELLY, A. E	4
KIRCHGASSER	1
KNOWLES, EDWARD R	57
KOWALEUKOFF, W	3
LLOYD'S REGISTER OF SHIPPING	1
LOS ANGELES EXAMINER	1
LUDIN, ADOLF	2
LUMIERE ELECTRIQUE	1
MARYLAND PUBLIC SERVICE COMMISSION	1
MASSACHUSETTS BOARD OF GAS AND ELECTRIC LIGHT COMMISSIONERS	1
MASSACHUSETTS INSTITUTE OF TECHNOLOGY	1
MAYER, WM	6
MINISTERIO DA VIAGAS E OBRAS PUBLICAS, BRAZIL	2
MINISTERO DELLE POSTE E DEI TELEGRAFI	1
MUNICIPAL ENGINEERS OF THE CITY OF NEW YORK	1
NATIONAL ELECTRIC LIGHT ASSOCIATION	1
" " " " BOSTON SECTION	1
NATIONAL FIRE PROTECTION ASSOCIATION	5
NEW ORLEANS SEWERAGE AND WATER BOARD	1
NEW YORK (CITY) BOARD OF TRADE	1
NEW YORK (CITY) BOARD OF WATER SUPPLY	3
NEW YORK (CITY) DEPARTMENT OF WATER SUPPLY, GAS AND ELECTRICITY	1
NEW YORK (STATE) DEPARTMENT OF LABOR	4
NEW YORK (STATE) PUBLIC SERVICE COMMISSION	1
NORSA, RENZI	1
OESTERREICHISCHER INGENIEUR UND ARCHITEKTENVERE N	2
PENROSE, CHARLES	1
PIERCE, A. L	2
POLYTECHNIC INSTITUTE OF BROOKLYN	4
PREFECTURE DE LA SEINE	1
PULLIGNY, L. DE	1
REED, HENRY D	1
SAINZ, J	1

SCHOOL OF ENGINEERING OF MILWAUKEE	1
SIMON, ARTHUR	1
SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION	1
SOCIETY OF CHEMICAL INDUSTRY	1
SOUTHWESTERN ELECTRICAL AND GAS ASSOCIATION	2
STREET RAILWAY ASSOCIATION OF THE STATE OF NEW YORK	1
TELEPHONE PIONEERS OF AMERICA	1
THOMPSON, S	1
ULISSE DEL UNONO	1
UNDERWRITERS LABORATORIES, INC	1
U. S. BUREAU OF NAVIGATION, DEPT. OF COMMERCE	1
U. S. BUREAU OF STANDARDS	1
U. S. DEPARTMENT OF AGRICULTURE	4
U. S. WAR DEPARTMENT	1
D. VAN NOSTRAND COMPANY	4
VERBAND DEUTSCHER ELEKTROTECHNIKER	1
WEAVER FUND	1
WEIN, SAMUEL	1
WESTERN UNION TELEGRAPH COMPANY	1
WOODBURY, C. J. H	1

Summary of Accessions
May 1, 1913—April 30, 1914

Donors	185
Exchange	170
Purchase and old material	122
Total accessions	477

Statistics of Library May 1, 1914

Source	Vols.	Pamphlets	Valuation
Report of May 1, 1913	16,843	1652	$34,432.75
Purchase	109	1	218.25
Gifts and exchanges	318	37	645.25
Old material accessioned	12		24.00
	17,282	1690	$35,320.25

In the following table are given figures for the total valuation of the library property, no allowance having been made for depreciation:

Books	$35,320.25
Stacks	1,761.05
Furniture, catalogue cases, etc	376.00
Wheeler cases	930.00
	$38,387.30

The following tabulation gives the state of the accounts from which the Library Committee is entitled to draw:

Mailloux Endowment Fund ($1,000)

(Proceeds for the maintenance of specific sets of periodical publications).

Balance May 1, 1913	$77.55	Expended	$26.75
Interest	45.00	Unexpended	95.80
	$122.55		$122.55

International Electrical Congress of St. Louis, 1904, Fund.

(Proceeds available for the purchase of non-American international electrical literature).

Invested in New York City 4½% Bond	$2268.00
Additions to the Fund	81.00
Total Fund	$2349.00

Balance on hand May 1, 1913	$395.24	Expended	0.00
Interest	90.00	Unexpended	485.24
	$485.24		$485.24

During the year the General Library Fund, amounting to **$284.92**, and the Weaver Fund, amounting to **$6.69**, were expended for the purchase of books for the library, and therefore these two accounts do not appear in the statement given above, nor are these amounts included in the record of expenses given below.

Institute Expenses on Account of Library.

Share of salaries of librarian, assistants, cataloguer and desk attendant (one third from May 1, 1913 to December 31, 1913, and one-fourth for remainder of year ending May 1, 1914)	$2600.40
Share of library's supplies, etc.	137.02
*Books and periodicals	150.18
Insurance	88.21
Binding	334.85
	$3310.66

*To obtain the total expenditures for books for the year, the amounts expended from the General Library Fund and the Weaver Fund should be added to this sum, thus making the total expenditures for books $441.79.

Library Attendance

	Day	Night	Total
May 1913	793	213	1,006
June "	579	142	721
July "	652	closed	652
August "	612	79	691
September "	715	197	912
October "	894	212	1,106
November "	856	235	1,091
December "	1,037	286	1,323
January 1914	1,115	302	1,417
February "	949	293	1,242
March "	984	339	1,323
April "	936	309	1,245
Total May 1913-April 1914	10,122	2607	12,729
Total May 1912-April 1913	7,667	2280	9,947

Presented at the 31st Annual Convention of the American Institute of Electrical Engineers, Detroit, Mich., June 22, 1914.

THE EVOLUTION OF THE INSTITUTE AND OF ITS MEMBERS

President's Address

BY C. O. MAILLOUX

INTRODUCTION

THE constitution of this Institute prescribes that the president "shall deliver an address at the annual convention." The duty thereby assigned to the president becomes one of his last official ones, when the annual convention falls so near the end of the term of office, as it has in the last few years.

The realization of the approaching end of his term of office made one of my distinguished predecessors feel that his presidential address was a sort of "swan song." It is a cause for congratulation both to the Institute and to him that he has since then contributed several other very good "songs" which have received great applause both here and abroad; and his many friends and admirers all rejoice over the good prospects of his being heard from again, many, many times. The fact that so many of our past-presidents have retained a great interest in the affairs and welfare of the Institute, and have continued to work most loyally and zealously in its service, makes me feel that it would be misleading to ascribe a "valedictory" character to the president's address. I am very certainly not inclined to regard it, in my own case, as an incident of "leave-taking," since I feel the strongest desire and disposition to continue to serve the Institute to the best of my ability after I return to the ranks. I prefer to regard it in the light of a graduation-thesis, constituting one of the requirements for the "honorary degree" of "past-president."

THE DEVELOPMENT AND ACTIVITY OF THE INSTITUTE

The wondrous activity of this Institute, the enormous amount and the magnificent quality of the work which it does each year, are so full of interest and so worthy of attention, that they would easily furnish both the pretext and the inspiration for an interest-

ing and instructive address. To one who, like myself, had the privilege of "enlisting" as one of the founders, and who holds the diploma of charter-member of this Institute, its growth, its expansion, its work, and its achievements have been, from the beginning, and still continue to be, sources of increasing wonder and astonishment. There is, in truth, reason for us to be proud, even to the degree of exultation, over the fact that the American Institute of Electrical Engineers, the youngest in the family of national engineering societies in the United States, has pushed its way to the very first place among them all, not alone in point of membership, but in respect to its subsidiary centers of activity, *i.e.*, its Sections and Branches; also, and more especially, in respect to the number and the character of the contributions to original knowledge of which it has been the depositary and the means of dissemination; also in respect to the important role which it has played and the great influence which it has exerted in the entire world, in connection with questions of electrical units and standards and other matters calling for international conference and agreement. There is still at least one other respect in which it need not fear, but could challenge, comparison, (even if the list also included the sister societies in the rest of the world), namely, the proportion of active workers, *i.e.*, the proportion of members who give material evidence of their interest in the work, welfare and development of the Institute by making sacrifices not only of time, but of money through their zeal in its service. So far as I know, there is no other engineering or scientific society in the world which has the good fortune to have at its disposal, free of cost, the services of so many high-grade men.

This willingness and readiness to serve are evident in all the Sections and Branches of the Institute; and that is precisely what has made the plan of forming Sections and Branches so successful. It is in connection with the activities of the central body of the Institute, however, that the results of the devotion of our active members are most apparent and significant. Each month, men who hold most important positions gather at the Institute headquarters from all points, far and near—many of them coming a thousand miles, and some even a still longer distance—to attend meetings of directors and of committees. In general, the attendance at these meetings is surprisingly large. Frequently, there are many different committees holding meetings. Some of these meetings may begin a day or two before, and some may not be over until a day or two after "In-

stitute day." Very often, the committee works until a late hour in the evening, and, occasionally, it continues its work the next day. On at least two occasions, one of our most important committees, the Standards Committee, has been in session day and night for more than three days in succession.

The enthusiasm and the energy of these faithful and devoted workers, their evident desire to collaborate and cooperate to the highest advantage for the good of the cause, cannot fail to excite both wonder and admiration. The interesting and significant thing is that these men work with the same earnest attention and the same desire to produce substantial and useful results that they manifest in dealing with matters of most profound personal interest and importance. Not only is this high grade work done voluntarily, but the men literally pay for the privilege of doing it. The time and traveling expenses of some of these men amount to a large figure at the end of the year; and some of them have been serving the Institute, at that cost, for many years. Moreover, in many cases, notably in the case of chairmen and secretaries of committees, the work done at meetings is in reality only a small part of the total work done by them, which includes a great amount of correspondence. I have deemed it a duty to refer to the amount and the quality of the work that is done by the members without cost to the Institute, for two reasons: First, because the fact that there are so many devoted, earnest, faithful workers rendering such valuable services at more or less great personal sacrifice and expense may not be as well known to the membership at large and as much appreciated as it deserves to be; second, because I wish to pay a well deserved tribute of praise and to do honor to these men. It is a duty and it is also a great pleasure to me to pay a tribute of appreciation and of gratitude, here, for the Institute and for myself, to all these faithful, self-sacrificing workers, to whose zeal, loyalty, energy and generosity, the Institute is so much indebted for its success and for the reputation which it has achieved both here and abroad. It is precisely here, in my opinion, that we find the true explanation of the phenomenal growth and development of the Institute. It has often been remarked, by persons who are informed about the activities of the Institute, especially about the work of its important technical and special committees, that if the time and effort devoted to this work had to be paid for, even at bare cost, the Institute would need an enormous increase in revenue to carry it on. This is a modest

statement, however; it would be nearer the truth to say that the Institute obtains, without cost, more and better service than it could ever hope to procure for money.

The Evolution of the Institute

As members of the particular guild of technical specialists who are interested in, and dealing with, the applications of electricity, we all are more or less familiar with, and we all have reason to feel quite content over, what electricity has already done in improving existing facilities and in providing new ones for the world's work, and for the welfare, comfort, and happiness of its inhabitants. Nobody has had more frequent occasion or better cause than have the members of our guild, in the thirty years that have elapsed since its foundation, to realize and to appreciate the fact that we are living in an age of rapid evolution and of wondrous transformations. The fact is that the electrical engineer has played the leading parts in several of those transcendental, epoch-making developments in applied science, which have wrought so numerous and such radical and far-reaching changes in industry, commerce, trade, and even in the conditions of our daily life. Moreover, he is expected and he is preparing, to play an equally important part in many other new, forthcoming transformations of methods and facilities for promoting the progress of the world in the direction of higher civilization and greater benefits for mankind in general, through a more general and a better utilization of the sources of energy which nature has in reserve and which it will yield up to man as soon as he learns how to use them. Some of the electrical engineer's dreams of the past, that seemed, indeed, at the time, as fantastic and impossible of realization as fairy tales, have come true, and in a way which exemplifies the adage that "truth is stranger than fiction;" and he has kept on dreaming, of other, more wonderful, possibilities. Indeed, the realization of the supposed illusory dreams of the past, shows that he was more a clairvoyant than a dreamer.

The fact that our seemingly extravagant expectations have been so often realized in the past, justifies our having other extravagant expectations for the future. I think that we are entitled to say that the electrical engineer has been and that he is still a prophet as well as a minister of the world's progress.

The last century, sometimes characterized as the age of iron and steam, witnessed the great feats which the engineer accom-

plished with iron as a structural material and steam as a source of power. In the present century, steel is taking the place of iron, and electricity that of steam; and the engineering feats of the last century will pale into insignificance, when compared with the vastly greater engineering achievements and wonders which are to come, some of which are, in fact, already impending.

The great diversity in the subjects treated in the technical papers which have been presented before the Institute, in the last ten to fifteen years, shows that our field, instead of contracting and becoming more restricted, as it was feared at one time might happen, is enlarging rapidly, and in all directions. The opportunities for original research and experimentation, the chances of making discoveries, and inventions, and the openings for new specialties in technical work, are becoming more, instead of less, numerous and favorable. The general outlook is therefore encouraging. The prospects for the continuance of the growth and prosperity of our guild were never better, seemingly, than they are now.

Our success as a guild will be sure and complete, on condition, however, that we suffer no loss of cohesion or of solidarity as the result of increased specialization. We must bear in mind constantly that "in union there is strength." We must beware of segregation. This is a point of vital importance. There are delicate problems, here, for the Institute to solve.

The expansion of existing fields of activity or the advance into new ones, leads, very often, to the creation of new specialties. Some of these new specialties have assumed sufficient importance in the number of persons interested, and in the amount of technical work done by them, to attain to the dignity of substantially distinct branches of the engineering profession, for which separate technical societies have been created, like the American Electrochemical Society, and the Illuminating Engineering Society, the former of which is wholly and the latter partly a subdivision of the general field of electrical science and engineering. The subdivision of a large field into smaller independent or subsidiary fields of technical activity, may have been warranted in these two cases, but in other cases, where an attempt was made to follow their example, the results have been far less satisfactory; and it would have been better if, before founding new societies, the persons interested in new specialties had tried to utilize other facilities, including, especially, those which the Institute could offer them.

The technical committees of the Institute represent an honest and earnest effort which has been made—and with considerable success—to secure diversity in technical work and to give scope, individuality, and recognition to the various specialties and activities of the members or of groups of members of the Institute while avoiding their segregation into distinct small societies.

Each of our technical committees has the resources, the authority, and the prestige of the whole Institute; and every member of the Institute receives the full benefit of the activity and of the work done by the specialists constituting the committee. In effect, the result is the same as if every member belonged to a number of distinct societies specializing in certain subjects. This point is deserving of attention, as disclosing a feature which is not as well understood or as fully appreciated as it deserves, and as suggesting a field for further development.

So far as concerns the specialists themselves who take part in the activities of the technical committees, they are relieved of the responsibilities and burdens of keeping a small society alive to give scant support and limited publicity to their work as specialists. It is obvious that their work reaches a much larger number of people and does much more good when done under the auspices of the Institute. The Institute plan is based upon the principle that "in union there is strength," and on the economic advantages resulting from concentration of organization and administration. This plan fosters diversity by permitting activity in many directions that would not warrant the formation and could not maintain the existence of separate societies, and, for other specialties which could only hope to maintain a separate society on a small scale, and in a more or less precarious way, it offers a larger field and secures a larger audience, which, as we all know, is a consideration of the highest importance, because it gives the best incentive and is the best stimulus for doing work of the highest grade.

The preceding considerations reveal certain fundamental principles of efficiency and economy with which electrical engineers are all very familiar, namely, the importance of high values for the "diversity" and "load" factors in central stations. The Institute is, in effect, a kind of central station for the generation and distribution of a certain kind of electric "power" which is useful in the production of electrical "work" of greatly diversified character and of extreme importance, as a whole, to the vocation of the electrical engineer, and to the standing and the

advance of the electrical engineering profession. The analogy is perfect; centralization of activity and the superimposition of load-curves,—as the result of increasing the diversity-factor,—lead to a higher load-factor in the Institute, and in about the same way as in an ordinary electric power-station.

The Institute has abundantly realized its objects as we find them stated in the constitution, namely, " The advancement of the theory and practise of electrical engineering and of the allied arts and sciences, and the maintenance of high professional standing among its members." It has amply fulfilled its mission and its trust as the representative of the profession of electrical engineering in the broadest and most comprehensive sense. It gives shelter and support, encouragement and standing, to all the branches and specialties of the profession that are worthy. Its numerous Sections and Branches in North America, and its many groups of specialists working in various electrical fields, suggest a federation of states and territories, whose citizens are amalgamated into a coherent mass, in accordance with the old motto, " E pluribus unum," which the Institute exemplifies and glorifies.

In expressing my gratification over the good work done thus far by the Institute, nothing is farther from my thoughts than the wish to suggest or imply that there is not still more, indeed, very much more, good work ahead, waiting to be done. In truth, my feeling is that it would be very difficult to set any limits to the development of the Institute and its capacity for the further advancement and realization of its aims and objects. There will be no dearth of good opportunities in many directions; and I am confident also that there will be no lack of initiative, interest and effort on the part of the active members whose self-sacrificing devotion has done so much, as I have already indicated, to raise the Institute to its present high plane of efficiency. As time goes on, with better resources and riper experience, the Institute will be able to undertake tasks of greater magnitude and solve problems presenting greater difficulties than would have been possible hitherto.

There is one thought suggested by the foregoing sketch of the Institute's career which deserves to be impressed upon the minds of all its members. It is this: wherever in the extensive fields of electrical theory and practise a man may happen to be stationed, either by his own choice or by circumstances, whether he be genius or plodder, whether he be ambitious or modest, and

regardless of his specialty, or whether he have any specialty at all, there is room for him in these fields, there is a place for him in the Institute, and work for him to do, and there are benefits and honors waiting for him there. The Institute needs him, and he needs the Institute. Each can complement the other and can add to the other's "stature" in many ways.

Although the evolution of the Institute has been rapid, it has been, fortunately, also healthy. It has acquired a strong impetus which should carry it along steadily to ever wider scope and more fruitful influence. There is no reason why the Institute should not continue indefinitely to grow, to expand, and to increase its power for doing good to our profession and for developing a true professional spirit in its members. I trust that you all join me heartily in the wish that the Institute's career may be long and brilliant and I hope sincerely that you will all continue to do your best to help make the wish come true.

The Social and Civic Evolution of the Engineer

The preceding sketch of the evolution and development of this Institute has made it apparent that the particular branch of the engineering profession for which it stands before the world has attained a place of great distinction and high honor in that community of initiates and adepts known as the domain of applied science and technology and sometimes called the engineering world.

We might be content and satisfied to rest on our honors in that world, if it gave scope to all our aptitudes, if there were in it opportunities for the cultivation of all our faculties and the development of all our talents, and for the realization of all our ideals and aspirations. Unfortunately, that world is, after all, only a sort of technological workshop of vast proportions and of complex character, wherein one may develop great abilities and talents, it is true, but which aims at one thing only, the performance of scientific and engineering tasks and "stunts" of great commercial interest and industrial value to the whole world. It is not suited for the development of what we are wont to term the higher, better and finer side of human nature, including those important constituents of human character, built up of moral, ethical and spiritual attributes and of sterling qualities of mind and heart, those elements of general culture, high-mindedness and refinement, which breed the feeling and nurture the respect for ideals, and which develop those charms and graces of manner

that raise certain individuals to higher planes, and entitle them to greater respect and consideration than the rest, in human society.

I know that I need not dwell on the desirability of this kind of development, for I am sure that you all concede its necessity and its benefits for all classes of humanity. We all see quickly enough the " mote " that is in the eye of humanity in general; unfortunately, we do not always see the " beam " that is in our own eye, so great is the difference between looking at a thing in the abstract and in the concrete. That is what leads me to mention and to insist upon a point of great moment, not only to ourselves but to the whole world. It is this: we are further behind than we ought to be, in certain phases of that higher development which has just been alluded to; we are merely *followers*, whereas we ought to be *leaders*. I will admit that this condition has not been worse,—in many respects, it has, indeed, been far better,—in our branch than in the other branches of the engineering profession; but, the fact that we have been merely a little less blind to our opportunities and our duties than have our colleagues, is not an adequate excuse for our own delinquency. It is, perhaps, an accusation, as showing that, although more awake, we were not more alert or active.

One of the important objects which I have in mind, in this portion of my address, is to bring to the attention of electrical engineers,—and, incidentally, to the attention of all other engineers or classes of engineers who are " in the same boat,"—the fact that the acquirement of what might be termed " technical adeptness and dexterity," either individually or collectively, by the members of a profession, and the resulting increase of technical knowledge, accumulation of experience and data, and development of engineering methods, do not constitute the *summum bonum* of our professional life, and do not represent our only ideals or the sole end and purpose of our efforts, either in an individual or in a cooperative sense.

In extending and improving our relations to each other, through our Institute, we have laid the foundations for the development of a great guild. Let us remember, however, that in this case we ourselves may not, indeed, we cannot, be the sole judges of greatness. In reality, it is not *self*-recognition, but recognition of a class by *all other classes*, that counts. This is a point to which engineers as a class have given altogether too little attention. They have been too self-conscious

and self-centered; and they have not paid enough attention to their relations to the outside world. They have neglected to cultivate, and, consequently, they lack, the "*guild-spirit*",—that force which makes for the increase of prestige, influence and power of the guild, and secures for it the greater respect and consideration of other guilds and classes. It is high time that engineers should appreciate the importance of "taking their place in the procession", in a social, civil, and civic sense. While, in a professional class, the prominence of *individuals* may depend only or mainly on professional technique and achievements, the prominence, reputation or *caste* of the *class* or *clan*, as a whole, depends mostly, perhaps wholly, on the professional spirit—the "*esprit de corps*",—and on the ability, of the guild or class, to hold its own with the other guilds and classes, on common grounds, in social, civic ,political and other life, in the outer world. The next point of interest is that we really have duties to perform and are entitled to benefits, in that outer world. Moreover, our neglect to preempt or to occupy the place that belongs to us there, is a serious handicap to the prestige or influence of our particular professional class, and places it in a condition of relative disparity, before the world, as compared with other professional classes,—such as those of law, medicine, the fine arts, etc., which assert their rights and utilize their opportunities systematically.

When people speak of the "upper crust" of society, they imply and recognize, tacitly, the existence of lower layers, strata or classes in human society. It were indeed idle to deny the existence of classes, orders or groups in human society, any more than in the rest of nature. It seems to be in nature's general program. We find classes in the infinitely great worlds of the astronomer, and we find them in the infinitely small worlds of the bacteriologist, and in that of the physicist; and we find them everywhere between these two extremes, in the animal, vegetable and mineral kingdoms. An interesting example of the stratification of life was noted by the Prince of Monaco in his deep sea explorations. He found that the ocean had upper and lower "layers", or "tiers" of inhabitants, with an indefinitely great number of intermediate layers; moreover each kind of life, indeed each species of fish or animalcule, has its place at a certain depth, where it is "at home", and above or below which it is "out of its element", and may be so uncomfortable or so handicapped that it cannot live.

In this entire system of stratification in the universe, the relative location of each layer may be the result of accident or circumstances, but it is always liable to change. In the case of the "layers" of human society, some important changes have been effected rather suddenly by *revolution*; but most of the changes occur by the slower and better process of *evolution*. The important principle of the "survival of the fittest" is always in operation here, for there is continual battling by contending forces, the weak being crushed or thrust aside by the strong. The social or civic level occupied by any class in human society is at the point of balance or equilibrium between its own efforts to rise to higher levels and the efforts of other classes to prevent them from rising in order to take their place.

It is my opinion, as it is also that of many of my colleagues who have given careful thought to the matter, that as a professional class, we are entitled to occupy a higher station and to receive greater consideration and respect than have been accorded us by the public. I will not deny that we have made considerable progress in the direction of social respectability and higher civil status. A recent review of the evolution of the engineer, in the London *Times*, contains the interesting statement that "Considerably less than a hundred years ago engineers in the navy took rank *next below carpenters*". It is most gratifying to realize that, in the present day, in all the navies of the world, the engineer is in the "officer" class and that, at least in our navy, many of them have attained the "Admiral" class.

In an address on "the position of the engineer in civic and social life" presented before an Austrian technical society in 1877*, one finds ample evidence that the civil and social status of the engineer were then far from satisfactory to the engineers themselves. There is lament over the fact that the older professional classes, which had hitherto divided the world amongst themselves, looked upon engineers as "upstarts" and "intruders". We may still be considered "intruders" by the lawyers and politicians who fill the positions that we engineers alone are qualified to fill properly on public service, public works, and

* "Die Stellung der Techniker in staatlichen und socialen Leben." Vortrag des Herrn Hofrathes M.M. Freiherr von Weber. Gehalten am 17 Feb. 1877. Wochenschrift des Oesterreischischen Ingenieur und Architekten Vereins. Vol. II, Feb. 1877, pp. 59-60. Mar. pp. 85-88. (To be found in A. I. E. E. Library, Mailloux collection).

other commissions dealing mostly with engineering questions; but, at least, we are no longer called such harsh names. So we have made some progress,—just enough, perhaps, to show how far we are still from where we ought to be. The following passage in the address is well worth quoting: "Only in rare, exceptional cases, do we see engineers, even in matters of specifically technical character, vested with the authority which gives the ultimate final decision; indeed, they are never in the majority in the deciding body". Further on, in the same address the statement is made that the final deciding power in matters of the kind already mentioned remains "in the hands of laymen, and that the preponderating majority is composed of amateurs generally having a pronounced legal 'tinge".

These remarks, thirty-seven years old, need practically no revision for presentation before an American engineering society today. They still report the conditions quite correctly. The author calls attention to the fact that the civil and social status of the engineer are higher in France and in England than in the German countries. The engineer has never been regarded and treated in the former countries as an " upstart " or an "intruder". Of the French engineer, the paper says that his education not only equips him with the necessary knowledge and preparation for the fulfillment of all his technical duties, but that it makes him, in general culture, good breeding and social tone, equal to members of all other social classes, and that he is, therefore, received and acknowledged as such without any opposition. This passage is interesting as evidence of the benefits attainable from the kind of training which supplements technical adeptness and dexterity by the development of personal character along intellectual, cultural, social, civic and ethical lines. The article concludes as follows:

" Let us set aside small jealousies and controversies, let us help uplift each other reciprocally and in that way also raise ourselves in the estimation of the world,—let us stand fast, shoulder to shoulder, in healthy solidarity against the outside influences which begrudge us equality of privilege with the older professional classes, and which strive to shut us out;—let us show, by our own discipline, that we are qualified to advise, to direct, to lead, in the highest capacities, and let us be on all occasions gentlemen in disposition and deportment.

"The conquest of that position in civil and social life for which we are striving and which belongs of right to us, on the strength of our knowledge and ability, will then result without fail."

It would be difficult to improve upon this good advice even at this later date. The fact that it is still so good shows that it is

still needed; for the millenium expected thirty-seven years ago is not yet quite here.

This plea for the proper recognition of engineers, as a professional class, though based upon justice, is, in a sense, a selfish one, and, in urging it too strongly, we might expose ourselves to the charge of being actuated by a desire to gratify professional pride or vanity. Fortunately, the real motive for the evolution of the engineer in social and civic directions is one that is quite altruistic, for the benefits which will result from it for the engineering profession will be trifling in comparison with the benefits to the community, to the state, and to humanity in general. This may seem to be a broad statement, but it can be demonstrated.

We know that it is the engineer who, in the last hundred years, has effected the marvelous transformation in the material conditions of life and in the activity of communities which are startling to the historian, and which seem revolutionary to the superficial observer. The engineer has been too busy himself with the multifarious details of this gigantic task to note that what he has done has, in reality, reacted upon the whole structure of civilization to an extent so great that profound alterations, if not entire remodeling and reconstruction, are needed to restore balance and equilibrium. Now, in this task of industrial, social, economic, and political rearrangement and readjustment, there is work for all classes; and, considering the highly technical character of many of the problems involved, there is, especially, much work for which the training and experience of the engineer are important if not indispensable qualifications. It is here that we need the voice and authority of the citizen who is also an engineer; but his place is taken and his authority assumed by the lawyer, the politician, the agitator and the utopist, each having as little useful technical knowledge as the other, but each presuming, nevertheless, to be an expert and an authority on questions that are beyond his ken. Let us note here a significant fact. Public opinion holds so much consideration and has so much respect for the older professional classes,—law, medicine and theology,—that it would not tolerate the suggestion that the tribunals of justice should be administered by others than jurists, that questions of sanitation or hygiene should be decided by others than medical men, or that moral questions should be settled by others than clergymen. When, however, it comes to questions involving scientific and engineering knowledge, public opinion seems to be satisfied to let them be discussed and settled by anybody whatever, preferably by *others* than engineers.

In older times, men could qualify for handling the problems of the civilization of their day without reference to technical science, as knowledge of law and religion was the fundamental requirement. A very little science went a long way in an age when sophistry and credulity were at a premium. As a result of the rapid progress of civilization along scientific lines, the importance of law and religion now sinks into insignificance, in comparison with science and technical knowledge as qualifications for dealing with the problems presented for solution. It does not require much thought or imagination to see that, in a society which is becoming daily more and more dependent upon science and engineering for its welfare and well-being, aye, for its very existence, there is more and more room and need for men of technical training at the helm in public affairs.

Some thirty years ago, the then president of these United States stated that " we are confronted by a condition, not a theory." Today, we have a different state of affairs. We are confronted by both conditions and theories, more especially by a great number and variety of theories, many of them of questionable soundness. This conglomerate condition is owing to the fact that we have too many " quacks", and not enough " doctors", in economics.

A sage of bygone times uttered the aphorism that there is no royal road to learning. Now, the world would not be so much disturbed or inconvenienced, if it were only royalty that aspired to acquire learning without having to pay the price. Unfortunately, that disposition has become epidemic at the present time, and what is still worse, the appearance is often accepted for the reality, so far as knowledge is concerned, more especially knowledge of civics and economics.

The framers of the constitution of the United States, in making a general statement that " all men are born free and equal," without making it clear that they meant freedom and equality in a civic and legal sense, rather than in a social or intellectual sense, left room for much misunderstanding and confusion. The untutored mind finds encouragement here for the notion that one man's opinion is as good as another's. He does not distinguish between the *right* to express an opinion, which is a matter of *law*, and the *value* and *authority* of that opinion, which are matters of *knowledge*. He forgets that while the right may not be disputed, the authority may be both disputed and denied. This self-constituted authority is a source of great

mischief, and it is, perhaps, the indirect cause of much of our social unrest or political inconsistencies and our economic disturbances. We are forced to realize and to admit that it puts a premium on ignorance.

The same process of reasoning that makes a man think he is an authority on all political questions makes him a partisan of direct legislation in its most radical forms. Instead of matters being improved, they are made worse. The reason can readily be seen. The burdens thrown upon the individual increase in proportion with the responsibilities which he assumes. In presuming to deal with and pass upon all civic, economic and political questions directly, instead of delegating them to representatives, he assumes implicitly the responsibility for informing himself about every matter, and getting at least as intelligent a grasp and comprehension of it as the representative is presumed to have. But here is precisely where the trouble arises. Many of the questions which he has undertaken to answer for himself, in doing away with representatives and proxies, and in becoming his own authority and guide, are questions involving and requiring more or less thought and study and inquiry into facts. It is work of a kind for which the average citizen has not the time or the inclination, even if he had the aptitude and the training. How can enlightened thought and opinion and rational action be realized under such circumstances? It seems natural to expect that most of the untutored and indifferent minds in the community will either jump at conclusions or arrive at them in a very superficial way, very much as one may try to get the news by merely reading the heavy headlines in a newspaper. In such a case, it is very important that the headlines should be set up by men who are intelligent, well informed and honest.

It is a momentous question which is asked when we inquire whither the untutored citizens, who constitute always such a large part of the whole mass, will turn to read these headlines, in their search for information; and the answer is far from reassuring. Some may read them in the sermon of a popular divine who is trying to fill the pews by observations on civics, economics, and other technical subjects of which he knows precious little. Others may read them in the speeches and harangues of agitators and fanatics, and no doubt many others find them in the corner saloons in the vaporings of some would-be sage, who, after finding inspiration at the bar, tries to imitate the sapient " Mr. Dooley " in solving the world's problems.

The sum total, the net result, of all this dilettantism is a condition wherein the blind are leading the blind. All this confusion, and all the blundering which it entails, could be and may be avoided by putting men and things back into their proper places. In seeking for causes, we are brought face to face with important facts. First, the present disregard for knowledge and authority among the masses, and the transition from a state or condition where a few privileged professional classes or sects were the only ones who presumed and were permitted to think and pronounce on public questions, to a state where all classes and, in fact, all individuals, assume the right and authority to do so, are undoubtedly consequences of long-continued abuse of authority by those who presumed to be the oracles of the people, and made believe that they knew all about things which, in reality, they did not know. Second, it is mainly lack of *scientific* knowledge that has caused the old-time oracles to fall from grace in the popular estimation. The days when scientific facts could be over-ridden and overshadowed by rhetoric and oratory, are passed. An ounce of technical knowledge is worth a ton of imagination, when it comes to handling scientific facts. The public lost confidence in its oracles because it found out, in time, that it is more important for statements to be *true* than to be merely *plausible*. Third, the public is not to blame for not having given to men of scientific training an opportunity to enlighten and advise it in matters of scientific fact and knowledge. The blame lies with the men of the scientific class themselves, for having allowed the public, as a body politic, to remain in ignorance of their very existence, to say nothing of their qualifications. It is unfortunately too true that the civil and social status of the professional engineer are far from being well defined in the mind of the general public. Indeed, there are indications that the scientific education, training, and experience of the professional engineer are very little understood and appreciated in the community. It is not strange, therefore, that the professional engineer should, by many, be regarded as merely a higher grade of skilled mechanic or artisan. To remedy this condition, steps should be taken to inaugurate and carry on a campaign of education of the public, with the object of acquainting it with the engineering class. It is time that engineers should assert themselves as a class and let the public see that they satisfy very substantially the requirements of an intellectual class, and one of more than

average grade, as well as of high civic character; that, as such, they are qualified to render important service to the community and to the state, and are entitled to recognition.

I wish, at this point, to make it plain and emphatic that the kinds of service and of recognition that I have in mind are not of political, but more of civic, social and ethical nature and character. I would be sorry to see any body of scientific men become a political force and acquire ambition for political power. It would be a lamentable waste and perversion of mental energy of high quality and development. In the beginning of this portion of my address I spoke of the development of the higher and better sides of human nature, and of the evolution of character along the lines of highmindedness and refinement, as the path over which man can attain to the highest civic and social planes. It is my opinion that not only the engineering class is capable of this higher development, but that it can serve as a strong leaven to promote that development in the community. In a word, I believe that, just as engineering has helped materially to improve physical conditions, so the engineering class can help materially to improve civic, ethical, economic and even moral conditions, in modern life. The education, the training and the experience of the engineer fit him especially for such a mission. He has to deal less with fiction and more with facts than most men of other intellectual classes. He learns early to understand and appreciate the value and the utility of scientific method and precision in his habits of thought and expression as well as in his work. He also learns early to distinguish between the classes of subjects with which he is competent to deal, and on which he may presume to speak authoritatively, and those classes of subjects which are not within his sphere or his scope, and in reference to which it would be absurd or even impertinent for him to pose as an authority. He knows that specialties in intellectual work arise from the limitations of individual mental aptitude and energy, and he is willing to concede that the specialist is likely to have more and better knowledge of a given subject than the amateur. He *might presume* to express an opinion on subjects involving *scientific* or *technical facts;* he *would hesitate* to express one on subjects involving scientific *hypotheses* or *theories;* and he *would be quite reticent* on subjects involving *metaphysical* considerations or speculations. The subjects of the class first mentioned may be presumed to be wholly within

his sphere; those of the next class are likely to be only partly so; and those of the last class are, as a rule, entirely outside of his sphere. The man who has been taught and trained to exercise such discrimination and discretion is qualified for sane, sound, rational, logical, thinking; he is apt to be more careful and accurate in his statements; he usually says what he means and means what he says; and his opinions are bound to carry weight and receive consideration. They make an interesting contrast with those of the man who undertakes to cover all subjects with equal "fluency". It is well known that, as a rule, engineers and scientific men are more conservative in their statements than most men of the other educated and intellectual classes. This is the result of a better appreciation of the limitations of all human knowledge and of the importance of precision in thought and expression; it is, in a word, the result of better intellectual perspective and mental balance. These qualities are very valuable in the citizen, in the member of a community, as they are known to be in the engineer entrusted with important tasks. They only need to be known to be appreciated. They should enable the engineer to command the respect and receive the consideration of the general public, for they are bound to place him on a high civic plane, and make him an exemplar for the rest of the community.

That is the position to which I would like to see the engineering class attain. The other educated intellectual classes have had their "inning,"—their opportunity. Ours is yet to come. Deserve success and you shall command it. We must deserve and we shall obtain the confidence of the community; and when we secure it we must retain it, by continuing to deserve it. The engineering class can scarcely expect to reach the goal at one bound. It must expect to attain the higher position to which it is entitled among the thinking and intellectual classes by successive stages. It should delay no longer, however, in making a start and in taking the first steps.

I have not by any means exhausted the subject. There is a great deal more to be said, but I shall be content if I have aroused your attention to the importance of not neglecting our evolution along social and civic lines, and beyond the purely technical and professional lines which we have hitherto looked upon too much as being our final goal and the highest realization of our ideals.

I will offer, by way of conclusion, some thoughts summing up the situation, which, I hope, will receive your careful considera-

tion and will be borne in mind by you as having an important bearing upon the further evolution, in a civic and social sense, of the members of this Institute.

I. The Institute has made most satisfactory progress in the development of the activities and forces which conduce to its efficiency, which enhance its merits and enlarge its reputation as a forum for the discussion of questions and the study of problems in theoretical and applied electrical science. Its evolution in that sense and direction has been rapid and healthy; and it bids fair to continue to expand its sphere of usefulness.

II. The membership of the Institute, as a whole, has shown extraordinary devotion and loyalty to its interests, and a most edifying zeal in constant efforts to place it on a high plane among the engineering societies of the world.

III. The members of the Institute, as a class, have great respect for high professional ideals and ethics, and they have given enthusiastic and strong support to all movements and measures tending to their development in the Institute.

IV. The members of the Institute, in common with those in the other engineering societies in this country, have paid but little attention to the cultivation of professional ideals outside of the Institute.

V. As electrical men we have pre-empted and we hold a high position in that inner world which constitutes the engineering hierarchy. We have not attained the same high relative rank and position in the outer world, in civil and social life.

VI. In spite of the wonderful achievements which we have performed and the great contributions to the progress of civilization for which we deserve substantially the entire credit, we do not hold the place in the social scale that is commensurate with our professional attainments and our social qualifications.

VII. We have measured our weight and influence as a class by reference to what we think of each other, and by our mutual respect and consideration for each other, forgetting that our social position and status are determined wholly by what the outside world thinks of us, or the respect and consideration which it accords us, or which we demand and obtain from it.

VIII. The time has arrived when the members of the Institute should develop a class spirit through which a man in the engineering profession can attain to the place and high honor and consideration to which he is entitled among the other professional classes.

IX. We must show to the rest of the world that engineers are, by education, training, and experience, as well qualified as any professional class, to discuss, and deal with, public questions and problems, and that in the case of technical questions we are better qualified than are the other classes.

X. We not only fail in our duty to our professional class, but we also fall short of doing our full duty to the community, by remaining silent, in the social and civil background, and by hiding the important light which we are most able to shed on many public matters, by virtue of our scientific and technical training.

XI. We must dispel the popular notion that clergymen, lawyers, physicians, and literary people are still, as in bygone ages, the incarnation of civic wisdom and the epitome of social philosophy, or that they still constitute the only available source of intellectual "high potential" and the only dispensary of advanced thought and knowledge concerning the problems of civilization and human progress.

XII. The engineering class must take its place on a social plane parallel with that of the other professional classes, and must claim, in connection with technical matters within its province, the same consideration and deference to its opinions and decisions that are shown to the other classes under similar circumstances.

Presented at the 31st Annual Convention of the American Institute of Electrical Engineers, Detroit, Mich., June 25, 1914, under the auspices of the Engineering Data Sub-Committee.

ENGINEERING DATA RELATING TO HIGH-TENSION TRANSMISSION SYSTEMS

SUB-COMMITTEE REPORT PREPARED BY THE CHAIRMAN

THE present report is an analysis of the engineering data received from 25 power companies, operating high-tension transmission systems, in answer to a printed list of questions prepared by the High-Tension Transmission Committee of the year 1912-1913, and sent by that committee to 105 power companies operating at 25,000 volts and over.

The present Engineering Data Sub-committee has received the replies to these questions and has analyzed the data therein contained as hereinafter presented. In making this analysis, the main purpose has been to present, as far as feasible, the data having general interest in a form which shall at the same time be compact and easy of assimilation. A considerable part of the data which is statistical has been consolidated in tables which show in parallel columns for the several reporting companies various items of interest returned. A second portion of the data received could be presented more intelligbly under the various topical headings to which it related and has been so offered. As a matter of convenience the reporting companies have been listed with a brief statement as to the character of each plant and an abbreviation of the title assigned to it for the purpose of identification, to avoid the reprinting of the full names of companies a large number of times in the body of the report. In addition to the above-listed data, the companies have furnished a large number of blue prints, drawings and maps, many of which contain valuable designs and constructional details. A considerable number of these has been reproduced in the form of cuts at the end of the report. To facilitate examination and to economize space most of this matter has been redrawn to present the salient information free from non-significant detail. Where useful, dimensions and similar data have been given in the reproduced drawings.

The original reports returned from the companies will be on file at Institute headquarters and open to the inspection of any Institute member, should further details be desired. Furthermore, in the list of companies below is given the name and address of the person by whom the report was submitted, and it is very possible that further information with regard to the apparatus or practise of that company referred to in this report, could be obtained by direct application to such person.

Neither the Engineering Data Sub-Committee nor the Institute assumes any responsibility for the correctness of the information here reported. The sub-committee has endeavored, however, to give a clear and fair report of the information offered.

The sub-committee wishes to express its thanks and appreciation for the freedom with which companies have reported and to acknowledge its obligation for the large amount of personal attention and thought which was required on the part of reporting engineers to answer the very comprehensive list of questions that was submitted. Certain reports in particular should receive especial mention as showing an unexpected amount of painstaking description and discussion of some of the most important and delicate problems confronting high-tension transmission engineers. The sub-committee believes that the comparison of experiences and practise herein set forth cannot fail to be of much value to the profession and will certainly be of great assistance to those engineers having high-tension plants to establish who have not the time and opportunity for the extended research that is necessary in the case of plants of the first magnitude.

LIST OF REPORTING COMPANIES

100,000-VOLT GROUP

Mississippi River Power Co., (Miss. P.) Keokuk, Ia.—St. Louis, Mo.
Stone & Webster Eng. Corporation.

The data returned cover a double trunk line electrification. It represents the very heaviest type of large capacity transmission line and is recently completed. The report is a most valuable one.

Great Western Power Co., (Gt. W'n. P.) California
P. T. Hanscom, Asst. to the President, 233 Post St., San Francisco, Cal.

The data returned cover a large capacity trunk line electrification across the state of California from the Sierra Nevada Mountains to the neighborhood of San Francisco. A very valuable report. This plant has been operating several years.

YADKIN RIVER POWER Co., (Yad. R. P.) North Carolina
R. J. McClelland, Chief Engineer, Electric Bond & Share Co., 71 Broadway, New York.

The data returned cover a trunk line electrification of medium capacity, connecting a large hydroelectric development supplementary to a previously existing system, and is but recently finished. A valuable report.

PACIFIC GAS & ELECTRIC COMPANY, (Pac. G. &. E.) Central California. San Francisco.

This is one of the largest, oldest and most diversified companies in the country.

CHILE EXPLORATION Co., (Ch. Ex.) Chile.
Percy H. Thomas, Consulting Electrical Engineer, 2 Rector St., New York.

This line, which is not yet in operation, is a large capacity trunk line for supplying power for operating a very large copper mining development, including the electrical refining of the metal at the mine. It is notable as transmitting power from a power-house at the ocean to a mine at an elevation of 9,000 feet.

NOTE. One company ("X") did not wish its name used. It is a large system in a bad lightning district. It has a very large, widely distributed power load.

85,000-VOLT GROUP

MEXICAN LIGHT & POWER Co., (Mex. L. & P.) Necaxa to the City of Mexico.
C. B. Graves, General Manager, Apartado 124, bis., Mexico, D.F.

The data returned cover a number of transmission lines in a very large system which collects power from a number of power stations and distributes it over a wide range of territory. This plant has been operating for a number of years. A very full and useful report.

APPALACHIAN POWER Co., (Ap. P.) Bluefields, W.Va.
H. W. Buck, Viele, Blackwell & Buck, 49 Wall St., New York.

This plant, which is very modern, illustrates the problem of the distribution of power in moderate quantities to a distributed load. It has been operating but a short time. A valuable report.

SOUTHERN SIERRAS POWER Co., (Sou. S. P.) Southern part of California.
R. G. Manifold, Engineer, Riverside, Cal.

The data returned cover a high-voltage construction for an extremely long-distance transmission and operates in conjunction with a previously existing system of large extent. It operates at present at a lower voltage than ultimately contemplated. A valuable report.

PENNSYLVANIA WATER & POWER Co., (Pa. W. &. P.) Holtwood to City of Baltimore.
J. A. Walls, Chief Engineer, Baltimore, Md.

The data returned cover a heavy trunk line electrification in a very difficult lightning district, receiving power from the well-known Susque-

hanna River hydroelectric development. The engineering of this line has been particularly carefully worked out and the report is especially full and valuable.

60,000-VOLT GROUP

WASHINGTON WATER POWER CO., (Wash. W.P.) Washington.
O. F. Uhden, Chief Engineer, Spokane, Wash.

The data returned cover a new trunk tower transmission line and also standard 60,000-volt wood pole construction. This is part of a very large and widely distributed system. A valuable report.

TORONTO POWER CO., (Tor. P.) Ontario. Canada.
F. G. Clark, Chief Engineer, Toronto, Ont., Canada.

This is a large-capacity trunk line through a bad lightning district, from Niagara Falls to Toronto. A good report.

SAN JOAQUIN LIGHT & POWER CORP., (San. J. L. & P.) California.
Lloyd N. Pearl, General Superintendent, Fresno, Cal.

This is a widely spread distribution system using wooden poles in the Southern Central district of California. A particularly dry climate.

NIAGARA, LOCKPORT & ONTARIO POWER CO., (Niag. L. & O.P.) Western New York.
L. C. Nicholson, Marine Bank Building, Buffalo, N.Y.

This is a double trunk line through the western part of New York State in a very bad lightning district. This plant has been in operation a number of years and its engineering has been very carefully studied. A valuable report.

PORTLAND RAILWAY, LIGHT & POWER CO., (Port. R.L. & P.) Oregon.
O. B. Coldwell, General Superintendent, Broadway, Portland, Ore.

The data returned cover some of the more modern construction of an extensive generating and distribution system of large capacity. A valuable report.

SOUTHERN CALIFORNIA EDISON CO., (Sou. C.E.) California.
J. A. Lighthipe, Los Angeles, Cal.

The data returned cover a portion of a large and well-known system feeding into Los Angeles, Cal.

CHIPPEWA VALLEY RAILWAY, LIGHT & POWER CO., (Ch'a. V.R.L. & P.) Wis.
Eau Claire, Wis.

WESTERN STATES GAS & ELECTRIC CO., (W. St's. G. & E.) California.
Stockton, Cal.

The data returned cover an extensive distribution system in Central California. Wood-pole type of construction.

PUGET SOUND TRACTION, Light & Power Co. (P. S. T. L. & P.) Wash.
John Harisberger, M. T. Crawford, S. C. Lindsay, Seattle, Wash.

The data returned cover a large generating distribution system around Seattle, with modern transmission lines. A portion of the plant has been in operation for a number of years.

CITY OF SEATTLE LTG. DEPT. (City S. L. Dpt.) J. D. Ross., Seattle, Wash.

25,000-50,000-VOLT GROUP

UTAH LIGHT & RAILWAY Co., (Ut. L.R.) Utah.
O. A. Honnold, Electrical Engineer, Salt Lake City, Utah.

The data returned cover a portion of a very extensive system centering around Salt Lake City, Utah.

CANADIAN NIAGARA POWER Co., (C.N.P.) Niagara Falls, Canada, and Buffalo.
L. E. Imlay, Superintendent, Niagara Falls, N.Y.

The data returned cover a trunk line from Niagara Falls, Canada, to Buffalo. It represents four heavy capacity lines, parts of which have been in operation a number of years.

MT. WHITNEY POWER & ELECTRIC Co., (Mt. Wh'y. P. & E.) California.
Fred G. Hamilton, Superintendent, W D., Visalia, Cal.

A transmission distributing company located in irrigating district of Central Southern California.

UNION TRACTION Co. (Un. T.) Indiana.
G. H. Kelsay, Anderson, Ind.

The data returned cover construction of an interurban electric railway system of wide extent.

TABLES

Tables I to V, inclusive, herewith, give statistical information as to the several companies and are self-explanatory. Where the information submitted has been too extended to incorporate in the table, it is given in the following notes.

NOTES REFERRED TO IN TABLES

NOTE 1. Angles are turned by shortening standard spans and taking only part of angles exceeding 10 deg. on any one pole. Below 10 deg. the following table is used:

Angle	Span
0 deg.	600 ft. tangent.
2	500
4	400
6	300
7	200
8½	100
10	50

On angles over 50 deg. the last tangent span is made 300 ft.—the first and last angle spans are 50 ft. with an angle of 5 deg., and subsequent spans are 50 ft. with 10 deg. angle each.

Vertical angles are similarly handled.

NOTE 2. Right angles and heavy angle corners are turned by specially guyed dead end poles, Fig. 6, —angles under 10 deg. turned by standard poles guyed, and angles from 10 to 30 deg. are made on two or more poles. Vertical angles are not specially constructed except as to guying.

NOTE 3. Mex. L. & P. reports that the altitude is important. Gaps are set as follows:—Necaxa, altitude 2950 ft., voltage 85,000, gap 6 in.; El Oro, altitude 8000 ft., voltage 81,000, gap 6 in.; Pachuca, altitude 8000 ft., voltage 84,000, gap 7 in.

NOTE 4. Lumping together total interruptions and partial interruptions, and in the latter including even minor losses of load, such for instance, as a direct current breaker on a synchronous motor generator set opening up, although the synchronous apparatus holds in, we have the following percentages:—

Lightning	50 per cent	
Distributing cables	25 "	
Miscellaneous	25 "	—including buzzards on transmission line, operators' faults, and machinery breakdowns.

NOTE 5.

Floods and washouts on line	50 per cent
Pole tops burning off or failure of insulators	25 "
Errors in operation	5 "
Malicious interference	20 "

NOTE 6.

Lightning	70 per cent approx.
Wind, rain, sleet, etc.	10 " "
Interference	5 " "
Errors	5 " "
Miscellaneous	10 " "

NOTE 7. a. 1907—1912, possibly 10 or 12.
1912, possibly 10 or 12.
1913, possibly 5.

It is almost impossible to tell whether these insulators were punctured resulting in their breaking, or whether they cracked due to a spillover and then punctured. With the new insulator or Hirt type very little damage can be done by spillover.

b. From 1907—1912, about 150 insulators lost.
1912—about 75 insulators lost, and about 200 others changed on account of cracks.
1913, about 200 insulators changed on account of cracks and probably 50 insulators lost.

NOTE 8. The telephone system is protected by:—

a. A No. 8 steel ground wire carried on the same crossarm as the telephone wires, and on the side toward the transmission line.

b. Drain coils at terminals and at the two substations.

c. Vacuum arresters and spark gap at all telephone stations permanently connected to line. Aluminum cell arresters at terminals and at Hulls substation.

d. Insulating transformers at power house and substations.

NOTE 9. Telephone wires transposed according to "A", "B"-"C"-"B" system. "A" transposition between pairs; "B" and "C" transposition between wires of each pair.

NOTE 10. No standard distance for transposition. Our 28 mile two circuit tower line has three complete cycles in each circuit. The majority of pole lines have a transposition every mile (one cycle every three miles). Where our high-tension lines parallel foreign telephone or telegraph lines, transpositions are made every 1/3 mile.

NOTE 11. Long fuses (30 inches long) with spark gap to ground. At all stations "bleeder" coils with middle point grounded are installed. Operator must stand on insulated platform to use telephone.

NOTE 12. Reactance coils are used in main low-tension buses in the power house between groups of generators.

NOTE 13. Between the low-tension bus and the transformers at the power house, and between certain sections of the bus at the power house and at the substation.

Short-circuit current on transmission line at full voltage in power house, right outside the power house, is about 5 to 6 times normal full load current at start.

Without these reactances the starting wave of the short-circuit current at the same point would be about 8 to 9 times full load current.

No objectionable features. These coils have been in service all year 1912 and 1913.

NOTE 14. The coils will be located between sections of 12,000-volt generator busbars and will limit the flow of current to the capacity of the bus section which it protects.

NOTE 15. Coils will have 6 per cent reactance, and will be placed close to terminals of the 12,000- and 15,000-kw. steam turbines.

NOTE 16. The factor of safety of new poles is entirely up to the judgment of the designing engineer, and depends greatly on the climate, kind of soil and economic conditions. Our towers were built to stand if all conductors were cut on one side, and no allowance was made for the tendency of the ground wires to support the tower.

Specifications for Towers.

Each crossarm will be sufficiently strong to withstand a horizontal strain, in any direction applied at the end of the crossarm of 5000 pounds; and a vertical strain applied at the end of the crossarm of 1000 pounds.

Each ground wire support will be sufficiently strong to withstand a horizontal strain in the direction of the line of 8000 pounds and a vertical strain of 1000 pounds.

Each tower will be sufficiently strong to successfully resist the turning moment due to the application of a horizontal strain in the direction of the line of 5500 pounds applied at the point of support of either ground wire; also of a horizontal strain in any direction of 3000 pounds applied to the points of support of any three of the conducting wires. It will also be sufficiently strong to successfully resist an overturning due to a strain parallel with the line of 5500 pounds applied at the points of support of the two ground wires or a total 11,000 pounds; also to a strain at right angles to the line of 5000 pounds applied at the points of support of the two ground wires or a total of 10,000 pounds; also to a strain of 9000 pounds in the direction of the line, which load will be considered as concentrated at the intersection of the middle crossarm and the center line of the tower, and simultaneously a horizontal strain of 500 pounds at the points of support of each of the six conducting wires and two ground wires or a total of 4000 pounds which strain will be in a direction transverse to that of the line; also of a stress of 12,000 pounds applied horizontally at center of gravity of wires either at right angles or parallel to the line. Accompanying the above mentioned horizontal stresses will be a vertical downward strain of 500 pounds applied to each of the supports of the six conducting wires and two ground wires.

In addition to the above specified stresses each tower will be subjected to stresses due to its own weight and to a wind pressure in a horizontal direction of twenty pounds per square foot on the superficial area of the tower. The strength of each tower will be sufficient to resist the combined action of all of the above stresses without permanent distortion.

NOTE 17. Old insulators assembled test 120,000 volts for 1 min. New insulators, each disk tested with a low capacity transformer having steep wave front for 2 min. of continuous static discharge over insulator. Strain insulators same test.

NOTE 18. A special test tower was constructed and tested with following tests and all towers were built as duplicates of test tower:—

Test No. 1. A horizontal pull of 12,500 lb. in a direction parallel or at right angles to the lines will be applied at the intersection of the middle crossarm and the center line of the tower.

Test No. 2. A horizontal pull of 4,000 lb. in a direction parallel to the line and applied at the ends of any two crossarms (aggregate pull 8,000 lb).

Test No. 3. A horizontal pull of 6,000 lb. in a direction of the line applied at the end of any crossarm.

Test No. 4. A vertical load of 1,500 lb. applied at the end of any crossarm.

The tower must withstand the above force without permanent distortion in any member, and if such distortion should take place the contractor must replace such members with others until the tower successfully meets the requirements of the tests.

All of the standard towers covered by this contact must then be constructed strictly in accordance with the design and sizes of material contained in the successful test tower.

NOTE 19. On three of the present four 22,000-volt circuits from Niagara Falls to Buffalo on the Canadian side are in use Electrose insulators which have been in service a considerable number of years. The fourth line which was installed in 1912 also uses Electrose insulators but of a radically different design planned to be puncture-proof in severe impact tests. Test and forms of these insulators are described in the Trans. A. I. E. E., p. 2121, Vol. XXXI, meeting December 1912.

NOTE 20.	Winds, floods, fires, etc.	35 per cent
	Interference, blasting stumps, etc.	20 "
	Lightning	5 "
	Failure in equipment or insulators,	15 "
	Miscellaneous and unknown,	25 "

NOTE 21. The foundations of towers consist of 7-ft. legs with foot piece, the whole generally loaded with stone and well backfilled.

NOTE 22. Material of insulators porcelain with slate glaze. (Slate glaze shows up arc smoke marks better than brown glaze and attracts the attention of gunners less, but does not show up broken petticoats as well.

NOTE 23. The towers were built for two ground wires, but only one ground wire located on apex of tower was erected. This makes the horizontal spacing from ground wire to conductor $7\frac{3}{4}$ ft. and the vertical spacing $7\frac{1}{2}$ ft.

NOTE 24. All standard towers set on earth stubs while the heavy towers are set in concrete.

TOPICAL TREATMENT

A large number of comments made by the various reporting companies on a number of topics of especial interest to engineers are here grouped together under their appropriate subjects as follows:

LONG SPANS (QUESTION A-19)

The following notes of interest were returned:

Miss. P. Longest span with standard tower and conductor 1425 ft.

The maximum span used on this line is 3200 feet, and occurs at the crossing of the Missouri River. This and other long spans are shown in plan and profile on the accompanying drawings (Figs. 30, 31 and 33.) The conductor cable in these spans consists of a $\frac{5}{8}$-in. high-strength galvanized 19 strand steel core overlaid with 20 strands of No. 10 B. & S. gauge hard drawn copper wire. The cable is filled with a compound for the exclusion of air and moisture. Each circuit is carried on a single tower line, conductors in a horizontal plane, spaced 20 ft. apart, with two ground wires 10 ft. above at point of support. These river crossing towers were especially designed and vary in height from 60 to 230 ft. above foundations. See drawings.

Gt. Wn. P. One span 2300 ft. on special towers; one 2740 ft.

with No. 000 B. & S. " Minot " stranded wire; conductor balanced by counterweights to give uniform tension—Figs. 3 and 4.

Mex. L. & P. One 1400 ft. with a difference in elevation of 350 ft.; cable size and towers standard.

Pa. W. & P. Longest span with standard conductors and towers 1280 ft. Longest span 1800 ft. with No. 0000 B. & S., 7 strand hard drawn copper and towers 115 ft. high over all above foundations. Span sag 120 ft. (6.7%). Distance between conductors, vertically 10 ft., horizontally 15 ft.—Ground wires above conductors—no trouble.

City S. L. Dpt. Longest span 780 ft. standard double-pole construction.

Wash. W. P. One 1500 ft., ¼-in. " Siemens-Martin " steel as conductor.

San. J. L. & P. Span across Kings River at Piedra, six 3/0 aluminum cables, carried about 1700 ft. across river and anchored on hillsides to cedar poles. Two sets of three wires each are attached to two poles, wires in a vertical plane six ft. apart and attached to poles with two Locke No. 273 strain insulators. Guys are placed for each wire and run to anchorage in rocks. About 200 ft. sag is obtained with wires clearing river about 150 ft. All wires swing in unison in a high wind and no trouble has been experienced.

Niag. L. & O. P. See drawing, Fig. 34.

C. N. P. See drawing, Fig. 8. The transmission line crosses the Niagara River at Buffalo where there is a span of 2192 ft., from a 150-ft. tower on the American side to a 202-ft. tower on the Canadian shore. The tops of these towers are at the same elevation. The line is then carried over the village of Fort Erie with a span of 1667 ft. to a 61-ft. tower on Bertie Hill. The top of this tower is 107 ft. below that of the High tower. The minimum clearance of the cables above the river is 130 ft. On the high towers the cables are arranged on 15-ft. triangles and on the Bertie Hill tower on 10-ft. triangles.

The twelve conductor-cables are made up of 19 strands of No. 10 B. & S. gage bi-metallic wire and are stressed up to 5400 lb. This tension is kept constant by counterweights on the Buffalo and Bertie Hill towers. The counterweights are supported by steel cables which run over sheaves at the top of the towers and are connected to each bi-metallic cable through two pairs of spool insulators. Drop cables pass down and through

the tower to the Buffalo terminal station and on the Bertie Hill tower to the bus-bars. The busbars and switches are so arranged that any circuit on the pole lines can be connected to any circuit on the long spans. At the high tower, the cables are connected to galvanized iron chains which rest on insulated saddles and extend about 13 ft. on each side of the tower. Jumper cables are carried over the saddles.

In addition, spans of 800 and 1435 ft. were reported by other companies and no cases of trouble.

SPECIAL FEATURES OF CONSTRUCTION (QUESTION A-20)

The following notes relate to special features of interest in construction:

Ap. P. All suspension insulators are ballasted with 30-lb. cast iron weights. See PROCEEDINGS A. I. E. E., February 1914, page 227.

Port. R. L. & P. Experience has shown that it is cheaper and quicker to erect steel towers in position from the ground up.

ANCHOR TOWERS ON TANGENTS (QUESTION B-13-15).

The following reports were made on the use of anchor towers on tangents:

Miss. P. Approximately every mile.

Gt. Wn. P. Average every two miles—designed to stand with all wires cut.

Ap. P. Two per mile—designed to stand with all wires cut.

Sou. S. P. Every five miles, designed for 24,000 lb.

Pa. W. P. At least every fifth tower—on average five to mile.

San J. L. & P. Poles guyed both ways every half mile, will stand with three conductors cut.

Niag. L. & O. P. Every mile on steel towers; every half mile on "A" frames; all to stand with all three conductors cut.

Sou. C. E. No, use line guys.

Ut. L. & P. Every 1½ to 3 miles, according to wind conditions; designed to stand 7000 lbs. at center crossarm in addition to stress on regular line towers.

C. N. P. Only at two ends of line and two intermediate curves; designed to stand all conductors cut.

DETERIORATION (QUESTION A-25)

The following interesting notes on deterioration were received:

Gt. Wn. P. Slight rusting where towers were not properly galvanized. Wires corrode.

Yad. R. P. Line two years old—no deterioration noticed.

Pa. W. & P. No deterioration observed upon examination of buried portions of galvanized towers. One particular set of gusset plates near top of tower showing signs of rust during 1913; no rust or deterioration elsewhere. No signs of deterioration in conductors. Insulators both on transmission line and in stores showing deterioration, due possibly to temperature expansion effects. About 4 per cent of insulators examined to show such deterioration, not due to electrical causes.

Wash. W. P. We have noted no deterioration in conductors. Some insulators placed in service in 1904-1906 indicate that they may have deteriorated, but as the manufacture of porcelain at that time was far less efficient than now, no results of long time tests on those would indicate what will obtain on the ones of later manufacture. Towers were placed in 1910, and no deterioration has been noticed.

Tor. P. Except for some deterioration of ground wire and hemp core of conductor, no deterioration noticed.

San J. L. & P. No deterioration noticed as yet—60,000-volt system in use only three years.

Niag. L. & O. P. Galvanized towers develop rust spots in about seven years. Insulators to some extent deteriorate by puncture of an occasional skirt. No noticeable deterioration of cable except by occasional burning by arcs.

Port R. L. & P. The transmission line has been in service less than two years and we have, therefore, no observations of deterioration except in the matter of insulators, there having been a considerable number of failures in suspension insulators and insulators in a strain position since the line was put in service.

Sou. C. E. Insulator shells crack, presumably due to expansion of cement or steel pin.

Ch'a V. R. L. & P. Insulators give more trouble with age.

Ut. L. & R. Wood poles with carbonized butts last 10 years in this climate.

Pug. S. T. L. & P. None, if proper factors of safety were observed in original installations. Steel towers have to be painted every two years, if not galvanized. Cedar poles rot off at the ground in from 15 to 20 years.

City S. L. Dpt. Poles rot at ground line.

DEFLECTION OF SUSPENSION INSULATORS (QUESTION B 20-21)

As to how much angular deflection of conductor was assumed under wind conditions and how much was actually observed, the following data were reported:

Miss. P. 26 deg. 45 min., with ½ in. ice, assumed.

Gt. W'n. P. 45 deg. assumed.

Yad. R. P. 45 deg. assumed.

Ap. P. 30 deg. on swinging of strings; held down by 50-lb. weights.

Sou. S. P. 45 deg. assumed—45 deg. observed on swings.

Pa. W. & P. Approximately 60 deg. Probably never more than 30 deg. angular deflection from vertical due to wind observed under either steady wind conditions or swings. No good records on actual angular deflection. Conductors do not swing violently, and angular deflection is not the same at all points in a span for one conductor, but is the same for all conductors. See drawing, Fig. 54.

Wash. W. P. 50 deg. assumed, 36 deg. observed.

Ut. L. & P. 60 deg. from vertical assumed, this value observed in swings.

DESIGN FACTORS OF SAFETY (QUESTION B-22)

As to the factors of safety provided in conductors, towers, against overturning foundations, and overhead ground wires, the following data were reported:

Miss. P. Conductors 2, towers 3, foundations 2, ground wires 2.

Gt. Wn. P. Conductors 2, towers 2, foundations 3, ground wires 3.

Yad. R. P. Conductors 25,000 lb. per sq. in.

Mex. L. & P. Conductors 2 and 3, foundations 1.5.

Ap. P. Conductors 2, 3, towers 2, foundations 5, ground wires 10.

Sou. S. P. Conductors 2.5, towers 1.7, foundations 1.7.

Pa. W. P. For conductors (alum.) up to elastic limit—towers tested for maximum designed strength at factory—foundations practically 4—ground wire just up to elastic limit.

Wash. W. P. For conductors elastic limit, for towers 1, for foundations 1, for ground wire 1. These factors are taken in view of the fact that the maximum load conditions assumed were very severe.

San. J. L. & P. For conductors 6, for poles 3.

Niag. L. & O. P. For conductors 1 (elastic limit), towers 2, foundations, 2.

Sou. C. E. For conductors 22,000 lbs. per sq. in working stress.

Ctiy S. L. Dpt. Factor for conductors of 3 over elastic limit.

Overhead Ground Wires as Part of Structure (Question B-23)

In answer to the question as to whether overhead ground wires are relied upon as part of the line structure most of the companies replied *no*, but the following comments were received.

Yad. R. P. Yes.

Pa. W. P. Ground wire gives some stiffness lengthwise of line, damping longitudinal vibrations of towers, but is not relied on as part of the mechanical supporting structure.

Ut. L. & P. No, but it undoubtedly acts as a guy wire.

Cutting Out of Load (Question C-1)

A loaded circuit is usually cut off by an oil switch, sometimes on high tension, sometimes on low tension. The following replies are noted:

Gt. Wn. P. Drop generator load and open generator oil switch on low-tension side. Do not switch on high-tension side.

Yad. R. P. (a) Reduce voltage 60 per cent and then open low-tension oil switch (b) Open low-tension oil switch at full voltage (c) Open high-tension oil switch at full voltage.

Mex. L. & P. Cut out sections of line one at a time loaded or unloaded. Experience shows that this method gives less trouble from surges on oil switches and switch bushings.

Opening Short Circuit. (Question C-2)

To open a short circuit that holds on, the following companies reduce the voltage of the generators:

Miss. P., Gt. Wn. P., Sou. C. E., C. N. P.

Note also the following comments:

Sou. S. P. The hydro-electric plants are tied in by non-automatic switches on the low-tension side while the steam plant has oil breakers with definite time circuit relays on the low-tension side. The high-tension switches in the main tower line are of the Bowie air-break type and are non-automatic. As operated at present, when short circuit occurs on tower line, the steam

plant breakers clear the southern end of the system of trouble, leaving the steam station with all load in that territory. The hydroelectric plants then drop voltage to low value and test for location of trouble.

Sou. C. E. Separate main system into sections and cut out step up transformers on high-tension side.

Automatic Overload Relays (Questions C 3-8)

Automatic overload relays are generally used, and in many parts of the various systems. The majority are definite time limit or inverse time limit.

The overload settings run from 100 per cent to 300 per cent overload, and the definite time limits from ½ to 10 sec.

A half dozen companies use overload relays of progressively greater time element distributed from the load to the generator.

Miss. P. Use inverse time limit automatic overload breaker to cut apart groups of generators on the 11,000-volt generator busbars.

Niag. L. & O. P. and *Sou. C. E.* report success with this selective action; *Yad. R. P.*, *Mex. L. & P.*, and *Wash. W. P.* report partial success.

Pa. W. & P. Automatic overload circuit breakers are used in connection with 13,000-volt cable feeders, station auxiliary transformers at both power house and substation, and transmission lines, in the last case, however, not the high-tension circuit breakers, but the low-tension circuit breakers of those transformers connected with the line being opened.

In connection with 13,000-volt cable feeders, we use inverse-time relays; for the transformers and transmission line, definite-time-relays.

(a) The lowest tripping current for the relays connected with our 13,000-volt cable feeders is 100 per cent overload, based on cable rating; with 700-1400 per cent overload these relays will trip in 1 sec. (inverse time).

(b) The relays for the substation transformers are reverse-power relays set to trip at 50 per cent over load in reverse direction, and connected with a three-sec. definite time element.

(c) The power house transformer relays trip at 140 per cent overload 7 sec. definite time.

Time-element relays are normally used with progressive timing of the elements. This refers particularly to the relay system used for the 13,000-volt a-c. underground cable system in

Baltimore, of which a part belongs to the Pa. W. & P. Co. and a part to our customers' distributing systems. The larger part of the relays for this system are Type C Westinghouse overload inverse-time relays improved by F. E. Ricketts's compensating coil, which produces a relay curve with less steep characteristic and for heavy overloads can be brought to approach a definite time. Both tests and experience have shown that this type of relay can give good selective action for several relays in series.

Bellows type relays were previously used in this connection but were found to be not sufficiently reliable and were replaced by relays of the type referred to above.

Westinghouse Type C, improved, reverse-power relays with selective element are also used.

These reverse-power relays are used at the sub-station end of two transmission lines working in parallel. When a short circuit, which is not cleared in any other way, occurs on one line, it will trip the low-tension side of transformers at the substation connected with this line, while overload or time relays will trip the low-tension side of the corresponding transformers at the power house. If the other transmission line is not affected, the reverse-power relays for this line will remain open. In order to give another device (arc extinguishers) time to relieve lightning arcs, these relays for the transmission lines are furnished with definite time-limit relays (W. Type E); these have at present the following setting:

	Circ. No. 1	Circ. No. 2
Power House..................	3 sec.	2½ sec.
Sub-station....................	1½ "	1 "

The different time setting for the two circuits is chosen in order to prevent one line from opening at the substation, while the other opened at the power house, in case both lines should be in trouble. As soon as one circuit is cleared, an interlocking device prevents the other from opening by any relay action.

If after the clearing of one of the two paralleled transmission lines, the other still shows the trouble the field will momentarily be taken off all the generators at the power house simultaneously, and restored again.

Should this action not clear the second line, the switches must be opened by hand. Our experience so far shows, however, that permanent line trouble (wires down, etc.) never has taken place on both circuits at the same time.

Pug. S. T. L. & P. Success generally but not always.

Aside from the *Pa. W. & P.*, the *Ut. P. & R.* and *Pug. S. T. L. & P.* are the only companies using reverse-energy relays; the former reported "always" act selectively—the latter does not state the result.

Note also *Cty S. L. Dpt.* Use Westinghouse Type C, reverse-energy relays which act selectively when the power factor does not drop too low as on a very heavy short circuit.

Dropping Synchronous Load (Question C-9)

The following report that they seldom or never succeed in carrying synchronous load through a heavy main-line short circuit:

Gt. Wn. P., Mex. L. & P., Sou. S. P., Tor. P., San J. L. & P., Port. R. L. & P., W. St's G. & E., C. N. P., Un. T., Cty. S. L. Dpt.

Other reports—

Ap. P. "Sometimes." Lightning arcs are frequently cleared by arc suppressers without losing synchronous load.

Pa. W. & P. Lightning arcs are frequently cleared without the least loss of load, by arc suppressers.

Wash. W. P. We have automatic switches on all lines feeding out of the different stations and when these act properly we very seldom lose any synchronous load.

Niag. L. & O. P. Save synchronous load by automatic arc extinguishers, when arcs only are involved.

Ut. L. & P. Yes, when short circuit is cleared in three seconds.

Pug. S. T. L. & P. Sometimes we can and sometimes we cannot. If the duration of short circuit is three or four seconds synchronous apparatus always drops out.

Cutting Out One of Two Parallel Lines (Question C-10)

In answer to the question as to when two lines parallel at both ends could be cut out without losing the load the following were received:

Miss. P. Two St. Louis lines parallel at both ends and have been separated in a number of cases automatically without losing the load.

Mex. L. & P. Four lines are operated in parallel and as a rule one line can be cut out without losing the load.

Ap. P. Sometimes.

Wash. W. P. Have such lines but cannot cut them out without losing load.

San J. L. & P. Lines are tied together at load end by tie-breaker set light; at supply end lines are separated by operator.

Niag. L. & O. P. Have tried this but have abandoned the attempt.

Port. R. L. & P. Yes, but cannot be automatically separated

Sou. C. E. All main lines, cannot separate.

C N. P. Cannot separate such lines.

Un. T. Cannot separate such lines.

Locating Trouble (Question C-11)

Practically all plants sectionalize the line, test with generator voltage and patrol to locate line trouble.

Yad. R. P. Use also a Wheatstone bridge method.

Niag. L. & O. P. Use a special loop test described in the Trans. A. I. E. E., June 1907.

C. N. P. Uses a loop test.

Distribution of Power between Power Houses and Regulation of Voltage (Questions 20 and 21)

No points of especial interest appear in answer to questions on how power distribution between generators and voltage regulation are secured.

Effect of Heavy Short Circuit (Question C-23)

As to the effect of a heavy short circuit near one power station on a large system:

Pa. W. & P. When a short circuit occurs near one power house, the effect of this depends entirely on how long a time it lasts.

(1) If it is a lightning arc on the transmission line it will normally be cleared by arc suppressor.

(2) If it is cable trouble on the 13,000-volt distributing system, it will normally be cleared by opening automatically the proper feeder switches. If the trouble hangs on for more than four seconds the fields of the generators will be destroyed and restored automatically at all three power houses simultaneously.

Operation With One Side Grounded (Question C-29-31)

In answer to a question as to whether the lines were ever operated with one side grounded, even for a brief period, the following were received:

Pa. W. & P. For a few minutes, no effect; ground was cut off by the time the ground resistance was red hot.

Ut. L. & R. All one night on 28,000-volt circuit; no effect except unbalancing of system.

C. N. P. For about two hours with no effect except a slight unbalancing of current in conductors.

Ap. P. For two hours with no effect.

Wash. W. P. For several minutes causing whole system to be unbalanced.

Gt. Wn. P. For about ½ hour; one oil switch bushing and one string of insulators punctured.

Sou. S. P. "No; effect too severe."

Tor. P. On several occasions for five to fifteen minutes, on one occasion four hours. On the occasion when the system was operated for four hours the ends of the cable that were down were 1000 ft. apart, the ground was highly charged and the barbed wire on the right-of-way fence was also highly charged. A man attracted by the display due to this ground walked into the charged area, then tried to climb the barbed wire fence and was killed. A dog approached the barbed wire fence some distance away and after investigation started for remote regions. Claims were made for damages to cattle. These were paid, although it could not be found that any cattle were really injured.

In operating on a ground we have no means of knowing whether or not the wires are down, and as it is possible that there may be two grounds miles apart with an open circuit in the conductor between, we consider it a very risky thing to continue such operation and would only do so as a last resort.

San J. L. & P. For two and a half hours on 60,000 volts; for one and one third hours on 30,000 volts. The effect was unbalanced voltage on the particular feeder having a ground; unbalanced load on nearest generating plant, private telephone line out of commission, troubles reported from Sunset and other telephone systems.

Niag. L. & O. P. On one occasion when neutral was not grounded, for two hours; effect "violent."

Pug. S. T. L. & P. For 10 minutes,—severe strains, discharging lightning arresters—telephone wires hot.

Relays in H-T. Ground Connection (Question C-32)

No plant of those reporting except *Pa. W. & P.* (see below) seems to have any protective relay in the ground connection

from the high-tension neutral, except for the fuse of the Nicholson arc suppressor.

Voltage Regulators (Question C-41)

The use of Tirrill regulators to control the voltage of generators is almost universal and there appears to be no exception to the satisfaction they give.

Failure of Oil Switches (Question C-43-44)

As to whether oil switches have ever failed to open a circuit, most companies report no trouble, but the following are noteworthy:

Mex. L. & P. Very rarely.

Sou. S. P. No, but signs of distress are often shown. Most of the trouble from oil switches occurs in the breakdown of bushings from lightning or surges.

Tor. P. H-3 oil switches have failed repeatedly when more than four 10,000-kw. generators can feed through them to a short circuit.

Niag. L. & O. P. Yes, from repeated operation on short circuit without overhauling.

Ut. L. & R. 4000-volt, three-phase oil switch on overload.

Sou. C. E. On short circuits; the system has outgrown the size of the switch.

Pug. S. T. L. & P. Oil switches which are type H-3 and K-10 have always opened short circuits successfully but sometimes the switches are nearly wrecked.

Working with Adjacent Line Alive (Question C-45)

Practically all companies except *Cty. S. L. Dpt.* work on one of two lines on the same poles or towers when the other line is alive.

Which Insulator of Suspension String Fails First (Question C-48).

As to which insulator unit in a string of units is most likely to be injured, note the following:

Gt. Wn. P. Insulator next to line, but in general it is hard to tell.

Pa. W. P. Flashovers damage first and last units preferably.

Wash. W. P. Nearly always the first and last of the string.

Port. R. & L. No difference.

Ut. L. & R. End disks.

Relative Reliability of Suspension and Strain Insulator Strings (Question C-49)

There is a difference in experience as to whether strain insulators are more likely to fail than vertical strings. *Port. R. & L.*, *Ut. L. & R.*, *Pa. W. P.*, *Wash. W. P.*, and *Yad. R. P.* say "no." *Gt. Wn. P.* and *Sou. C. E.* say "yes."

Reactance to Balance Charging Current (Question C-51)

Sou. S. P. has the following to report about the use of reactance coils to control the power factor of the line.

Shunt inductance coils are used at one end of tower line. These have loading value of 2000 kv-a. and are arranged for being cut in by steps. They have been found valuable in the tieing together of the two systems of plants, enabling the steam plant to get in with the hydro plants with little voltage disturbance, which there would be if steam plant had to raise voltage to value high enough to equal voltage at end of unloaded line; this is about 14 per cent high.

Mechanical Oscillations (Question C-52)

With regard to trouble with mechanical oscillations in the line note the following:

Port. R. L. & P. Trouble occurs at far end of 30-mile, 33,000-volt, 33-cycle line when fed from one generating station only and given a heavy load. Line pulsates and finally kicks out at generating plant.

Ut. L. & R. No trouble except wind swinging suspension insulators enough to break them.

Wash. W. P. No, except that ice falling off the end ones of a group of three spans allows the ice in the middle span to carry this span down too close to conductor in the position below.

Mex. L. & P. Two during earthquakes.

In addition to the above, note the following replies received to a special inquiry about mechanical oscillations:

Gentlemen: New York, April 13th, 1914.

On January 8th, the Engineering Data Committee, at the suggestion of Mr. L. E. Eustis, Superintendent of the Stone and Webster Engineering Corporation, sent a letter to a number of high-tension power companies asking for any available experience with mechanical vibrations or oscillations of line conductors. You may be interested in the enclosed summary of the replies received. Yours very truly,

Percy H. Thomas, Chairman,
Engineering Data Committee.

Replies to Letter of January 8th Relating to Experience With Mechanical Vibrations or "Oscillations" of Line Conductors

C. N. P.

"This phenomenon was experienced by us in the aluminum cables which originally spanned the Niagara River between Fort Erie and Buffalo. The vibrations were most pronounced when there was little if any perceptible movement of the air. The cause was doubtless due to the physical constants of the span cables and possibly their supports being such that they would readily respond to slight movements of the air. Our evidence of this is that when the tension was decreased, allowing the cables to sag a few feet below normal, no vibration occurred.

At first we had some trouble with the cable strands breaking at the end supports due to crystalization of the metal. This was overcome by inserting about ten feet of iron chain in each span where the ends are attached to the supports. The chains were then shunted with jumpers to provide the necessary carrying capacity.

After a few year's experience with aluminum cables at the long spans, it was decided to replace them with copper clad steel cable having much greater tensile strength. These cables are somewhat heavier than the aluminum, but are smaller in cross section. They are pulled up to the same elevation as the aluminum cables but due to the different physical constants no vibrations have been observed under any weather conditions."

Niag. L. and O. P.

"Please note that we have frequently noticed such oscillations but never have found any harm to result from them. Such oscillations are particularly noticeable on long spans, although they occur to some extent on all spans."

Oregon E. R.

"Wish to say that we have had no serious trouble from this source, and have had no data or experience along this line that would be of interest."

Tor. P.

"We have no spans comparable to the Mississippi River crossing at Keokuk, Iowa. We have, however, given consideration to crossing the Niagara River where we have had to figure on 4,000 and 6,000 foot spans. It was necessary for us

to consider mechanical oscillations of the cables due to changes in temperature, ice loading, wind, and the vibrations that would be started by short circuits, and we concluded that proper spacing, counter weighting and keeping the cables at suitable temperature by means of local currents from insulated transformers or generators, would afford us ample protection.

We have no spans over 1000 feet on our existing transmission lines and have had no troubles that we can assume are directly due to mechanical oscillations. We have had line interruptions during sleet storms which could probably be accounted for in no other way."

P. W. & P.

"The possibility of such phenomena was anticipated at the time our transmission line was designed and a special endeavor was made to so design the line as to prevent such oscillations. We believe that the many anchor towers used and the attention given to the conductor sags is responsible for our freedom from such trouble.

As stated in the previous answers, we did experience some troubles owing to the ground wire being stretched too tightly, so that it hummed and caused considerable vibration of the towers. It was found necessary to cut in additional slack into the ground wire. The ground wire had originally been strung very tightly in order to avoid interference between ground wires and conductors, due to the possibility of sleet collecting on the ground wire while being absent on the conductors. Also a tight ground wire was considered advisable in order that its period of vibration longitudinally might be quite different from that of the conductor."

"We have no evidence of mechanical oscillation on our 1,800 ft. span river crossings."

From Mr. Magnus Swenson, President,

Southern Wisconsin Power Company, Madison, Wis. (dated 1/21/14)

"In answer to yours of the 8th will say we have experienced no trouble from mechanical oscillation on our line, nor has the Peninsular Power Company in the northern part of this state."

G. Wn. P.

"Will state that we have no record of any one having observed this phenomena on our lines."

Pa. G. & E. (dated 1/20/14)

"This company maintains a large number of long spans on transmission lines, these varying from 200 to over 4000 ft. in length. On spans up to 1500 or 2000 ft. the conductor material is not of great importance, our experience being that there is very little choice between copper, aluminum, copper-clad, steel and other materials.

On spans of more than 1500 ft. we have found it desirable for mechanical reasons, to use either copper clad, or steel conductors.

The longest span we have is that known as the "Carquinez Strait crossing," where the distance between supports is 4,427 ft. The conductors on this crossing are of 7/8 in. plow steel, having ultimate tensile strength of 200,000 lbs. per unit cross section. These spans have been in successful operation at 60,000 v. for 13 years. There is a small amount of vibration in the conductor at the point of support during days when there is no wind blowing, but during times when the wind is blowing the hardest there is little if any vibration whatever at this point.

A year ago one of the conductors of this span was taken down and a section near the supporting saddle was tested to determine whether or not there had been any appreciable deterioration of the metal either from crystallization or from electrical causes. A careful analysis and test showed that the cable was in apparently as good condition as it was the day it was erected.

On another line we have installed a large number of spans of 6/0 stranded aluminum, ranging from 1200 to 1800 ft. in length. No trouble has been experienced on spans of this length from the causes mentioned; in fact, this particular line is considered one of the most reliable that we have.

In a few instances trouble has been experienced from the vibration of the conductor, which has resulted in the latter breaking at the point of support. These instances, however, are very rare and we have attributed the trouble to the fact that the length of span and tension in same were just right for the wind to cause excessive vibration. In every instance where this trouble has occurred, the insulator has been the ordinary pin type. The trouble has been corrected by setting another pole, and thus introducing another point of support in the vibrating span."

From Mr. Chas. I. Burkholder, General Manager,
Southern Power Co., Charlotte, N. C. (dated 1/20/14)

"I have to advise you that on our lines having suspension insulators we have not had any trouble due to mechanical oscillations of line conductors, except in the case of unequal distribution of load due to sleet unloading from the lines. This has never occurred when the sleet was forming but has occurred when the sleet was falling off of the wire, in cases where it happened that the sleet fell off of one wire, we will say, in a given span, and remained on another wire, and where the opposite occurred in an adjacent span. This would cause an accumulation of sag in the unloaded span, and in some cases the accumulation of this sag has been enough to cause an actual contact of wires which were strung with a 10 foot vertical spacing. To obviate this, we lengthened our middle cross arm 3 ½ feet at each end."

Wash. W. P.

"I beg to state that we have never noticed any mechanical oscillations of our line conductors.

At one time we had some trouble which we were unable to account for, and thought that possibly it might be due to such mechanical oscillation. To satisfy ourselves on this point we short-circuited one of our 60,000 volt lines, about four miles from our Little Falls power house, without noticing any oscillation whatever in the conductors. This short-circuit was thrown on the line when it was connected with a 5000 kilowatt generator at the station, and as far as I remember now the automatic switch was set for ten seconds definite time limit."

Port. R. L. & P.

"We wish to state that we have not experienced any trouble. We have observed, however, the presence of waves along the conductors in an 1800 foot river crossing span. These waves appeared to travel along the conductors even on a quiet day. They were apparent only by listening to the insulators at the supports and manifested themselves in very much a similar manner to blows struck against the conductors with a wooden mallet. As the crossing span was removed within a year after its installation, and has not been replaced, we have no occasion to report actual trouble resulting from the waves. The crossing span supports are each located a short distance from railroad tracks and the waves which we observed appeared to have been started by passing trains."

From Mr. A. J. A. Kean, Chief Operating Engineer,
The Michoacan Power Co., Guanajuato, Mexico. (dated 2/10/14)

"In this connection we wish to advise you that we had this trouble on one of our transmission lines some two years ago and were able to eliminate the difficulty by using special hangers made in the form of a bow. If Mr. Eustis would care to send to us details regarding his trouble we may be able to supply him some information which will be of assistance to him."

From Mr. W. B. Stone, Chief Electrical Engineer,
Jhelum Power Installation, Baramulla-Kashmir, India.

"I beg to inform you that formerly when we had long river spans we experienced trouble which I attribute to this cause. The line wires became crystallized through fatigue close to the clamps on the insulators, and when the first fall of snow came they invariably carried away this point. We have now removed all long spans."

From Mr. C. A. Sylvester, General Manager,
The Rio de Janiero Tramway, Light and Power Co., Limited,
Rio de Janiero, Brazil.

"We have had no trouble which could be traced to mechanical oscillation of our transmission line conductors.

Our 88,000 volt transmission consists of 3/0 conductors erected on Riter-Conley type of steel towers, six conductors per tower. We have several spans exceeding 500 meters, the greatest span being 590 meters. Observation of the oscillations indicate a considerable side swing during heavy winds, but the wires apparently always maintain their spacing of eight feet. This is probably due to the fact that they are of the same weight per foot, diameter, and are erected with the same tension. There is of course no unequal loading due to sleet.

It has been suggested that the vibration and oscillation of the wires may tend to break the conductors at the insulators. We have up to the present time observed no effect of that kind. The lines have been erected since 1907."

Location of Lightning Arresters (Question C-2)

Lightning arrresters are freely located either inside or outside, and universally close to the outlet of a station.

Duration of Discharge on Electrolytic Arresters (Question D-10)

There is no report of over 1 minute of actual continuous discharge on an electrolytic arrester. At least two companies cut them out if they begin to discharge steadily.

Effectiveness of Overhead Ground Wire

With regard to the opinion of companines on the effectiveness of overhead ground wires as a protection against lightning, note the following:

Mex. L. & P. We have had overhead grounded ground wires on our high tension transmission lines for the past six years. In practical experience we have found that this has given us an excellent protection. The number of cases of trouble due to lightning have been enormously reduced since the installation of these ground wires. We can definitely state that we consider their installation as effective and desirable.

Ap. P. There is evidence in favor of the effectiveness of overhead ground wires but it is not conclusive.

Pa. W. P. We have no reason to believe that the overhead ground wires have been of any benefit against lightning troubles.

Ch'a V. R. L. & P. We have wood pole lines 26 miles long without ground wire, there is 12 mile extension with ground wire same insulators and cross arms used; never had an interruption from lightning on 12 mile line; have 7 or 8 per season on 26 mile line and have many bad insulators that do not shut down line.

Ut. L. & R. Overhead ground wires on tower lines undoubtedly reduce static disturbances as interruptions are much less frequent than before.

Special Protective Devices (Questions E-1-4)

In certain systems, devices operating through circuit breakers or fuses have been installed for the purpose of automatically freeing circuits from arcs, either between line wires or to ground. The principle of operation includes the momentary short circuiting of the arc by automatic apparatus at some predetermined place which opens the circuit as soon as the orginal arc is suppressed. The following reports have been received bearing on such apparatus.

Pa. W. P. We are using the arc suppressor invented and designed by L.C. Nicholson of Buffalo, N. Y. This device consists in a general way of electromagnetic relay switches connected in

series with the main transmission line. The overload caused by a flashover produced by lightning closes these electromagnetic switches rapidly, and in this way short circuits the wires between which the flashover is taking place, with a fuse wire calibrated to blow in about 5-10 cycles. This device worked very successfully in 1912 and 1913. It is especially satisfactory when only a ground or a short circuit takes place between two of the transmission wires. In such cases, it saves all of the synchronous load. If a three-phase short-circuit takes place, the effect on the synchronous machinery is more serious. About 50 per cent of the load can, however, be saved, especially if the rotary converters, of which the main load consists, are separately excited, so as to prevent reversal of polarity.

With the Nicholson arc extinguisher are also connected certain electrostatic relays, intended to work in such a way that when one wire becomes grounded, a switch will be closed, and by this means, a fuse wire, which is timed to blow in about 1/2 second, will be connected between the wire which is grounded, and the ground. This device worked successfully several times. The electrostatic relays which initiate this action seem, however, somewhat less reliable than the magnetic relays, which get into action on short circuits on the line. The electrostatic relays are at present cut out of service, due to the fact that the principle they are based on will make them operate unnecessarily and thus produce undesirable complications whenever the voltage on the line for a moment is lowered artificially by operation of field destroying device.

In case the arc extinguisher as outlined above does not work, or does not extinguish the arcs, the field is automatically destroyed on all generators in all three power houses connected together, and after 1½ sec. the field is restored again automatically, and, normally a large part of the synchronous load will, in this way, be pulled into step again.

The relays, which in the main power house (Holtwood) actuate the field-destroying and restoring device are either one of the generator relays (in case of short circuit on the line) or the relay in the grounded neutral of one of the transformers connected with the transmission line; these relays act instantaneously themselves, but their action is delayed 4 sec. (by means of a definite time limit relay) in order to give other protective devices their chance. The main difficulty we have experienced with this device is to prevent the generators in the power house (water-

wheel driven) when some of their prime movers were on " hand control" (*i.e.* had a steady gate opening), from speeding up the moment the field was taken off and thus getting decidedly out of synchronism. When originally installed, the time the field was left open (*i.e.* short circuited with the standard discharge resistance) was 5 sec.; this time element has this year been cut down to 1½ sec. with the results much better in the above respect than formerly, and yet the time is apparently long enough to extinguish lightning arcs on the transmission line. The 1913 record until October 1st, shows that lightning has hit our lines 32 times resulting in three total interruptions, while the trouble was cleared successfully, with little or no loss of load, 18 times by arc extinguisher, 9 times by field destroying device, and two times by relays opening one of two parallel circuits.

Tor. P. The circuit-breaker type of arc suppressor was tried but was not a success. The Nicholson electromagnetic type is being installed.

Niag. L. & O. P. Uses both Nicholson automatic grounding and Nicholson automatic short circuiting devices.

LOWERING VOLTAGE TO CLEAR SHORT CIRCUIT (QUESTION E-11)

In reply to question as to whether the voltage of generator is lowered in case of trouble the following were received:

Miss. P. Yes, by hand and automatically.

Gt. Wn. P. Yes, by hand.

Yad. R. P. Yes, by hand.

Sou. S. P. Yes, by hand, expect to install device to automatically lower voltage at time of short circuit or ground on line.

Pa. W. P. See notes under Special Protective Devices (Question E, 1-4 above),

Wash. W. P. No, only when line is on a single generator as a separate system.

Tor. P. Automatically.

San. J. L. & P. No.

Niag. L. & O. P. No.

Port. R. L. & P. On special occasions by hand.

Sou. C. E. Yes, by hand.

Cha. V. R. L. & P. No.

C. N. P. Excitation is from induction motor-driven d-c. generators. The motors are supplied from busbars fed by the alternators which they excite. In case of a short circuit, exciter sets automatically slow down and reduce field excitation.

Pug. S. T. L. & P. Yes, have auxiliary relay on Tirrill regulator that prevents increase of field strength during short circuit.

Mt. Wh'y P. No.

Un. T. No.

USABILITY OF TELEPHONE LINES (SECTION F)

The conclusions to be drawn from the relies to the questions on telephone lines may be summarized.

In general no company can entirely rely on its telephone line when the power line is grounded and many cannot use their telephones while electrolytic lightning arresters are being charged. The effect of the grounding of the high-tension line is to make it noisy and to cause discharges over arresters and sometimes to cause telephone fuses to blow.

The following comments are noteworthy:

Gt. Wn. P. Most severe trouble is from a ground on the 100,000 volt line. This in general will cause a break over the insulation of the telephone line which is carried on 6,600 porcelain insulators. To quiet the line 2 kw. 2200/220 volt transformers used as drainage coils with the secondaries open were installed; these were successful.

Yad. R. P. The telephone line is said to be usable at all times and grounding of the transmission line to have no effect. This telephone line is from 500 ft. to one mile away from power line.

Sou. S. P. Telephone line not always usable. Most of trouble is due to mechanical faults occurring in telephone lines. Induction is also noticed. Arcing on horns of out-of-door switches is quite noticeable on telephone lines. Ground on transmission line makes phone very noisy.

Pa. W. P. Users of phones protected by lightning arresters and fuses on line side of instruments. Insulating transformers used at Baltimore end of telephone line.

Phone usable practically at all times during operation.

Phone not usable only at time of ground on transmission line or during charging of electrolytic arresters.

Troubles on transmission line blow fuses or burn arresters on telephone line occasionally. Sometimes burn out 'phones.

There has not been much trouble and talking is remarkably good on telephone lines—equally as good as Bell long distance lines.

Niag. L. & O. P. Heavy induction by grounds on power lines sometimes blows fuses on telephone lines at stations. Telephone is practically always usable due to bleeding coils.

Cty. S. L. Dpt. Induced currents have caused phone wires spaced 12 in. apart to wrap together. Line disturbances sometimes blow telephone fuses (¼ ampere). We do not attempt to use phones while a disturbance is on line.

NOTE: The following description of the protective apparatus used by the Georgia Railway and Power Company to shield its transmission line from disturbances on the high tension transmission line, together with an account of tests made thereon, has been furnished by Mr. E. P. Peck, Ass't Electrical Engineer.

The telephone line of the Georgia Railway & Power Company from Atlanta to Tallulah Falls, a distance of 87 miles, has No. 4 bi-metallic conductors, insulated with single disk, suspension insulators. These insulators have a dry flash-over test of 70,000 volts but it is the purpose of the company to connect two of them in series on the telephone line at the earliest possible date. The telephone line is strung on the main 110,000-volt tower line, about 10½ ft. from the lower power conductor.

The telephone line operates at a voltage to ground of approximately 5300 volts, when no drainage coils are connected. The voltage from line to line is very low, except in cases of insulation troubles on the main power line or on the telephone line.

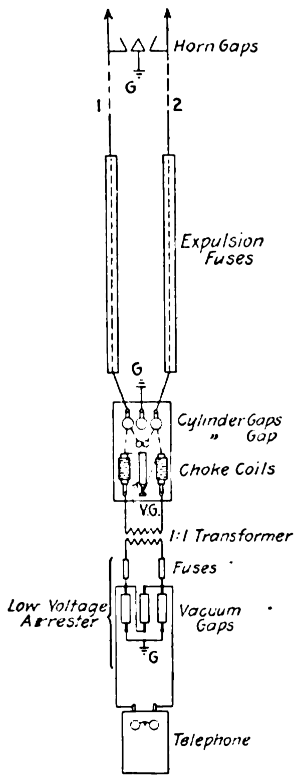
Trouble was experienced, due to the high voltage on the telephone line, and to remedy this, drainage coils have been connected at the Boulevard substation in Atlanta and at Gainesville substation. A drainage coil will be connected at the power house also, in a short time. A standard 15-kw., 2200-volt power transformer is used as a drainage coil. The 2200-volt leads of the transformer are connected to the line wires and the middle tap of the primary is connected to ground, the secondaries being left open.

With the drainage coils connected in Gainsville and in Atlanta, the voltage from the telephone line to ground is approximately forty-five volts, the drainage coils carrying a current of approximately 3.75 amperes, continuously, in the ground leg.

The telephones in all of the stations are connected to the telephone line through telephone transformers, insulated for 25,000 volts from primary to secondary.

A number of telephone transformers and telephones have

been damaged on this line, the damage resulting from lightning along the line or from leakage either on the main power system or on the telephone line. To stop the telephone and telephone transformer trouble a lightning arrester has been developed which gives promise of excellent results. The apparatus (diagram of connections shown herewith) consists of proper relief gaps which are protected by expulsion fuses. The most important part of this arrester unit is a vacuum gap adjusted to break down at approximately 350 volts and connected from line to line. Adjustable cylinder gaps are connected from each line to ground and other cylinder gaps are connected in parallel with the vacuum gap. Choke coils, wound on porcelain cores and with turns very heavily insulated, are connected between the gaps and the telephone.



The action of the arrester in case of high voltage on the telephone line is as follows: A high voltage impulse being impressed on the lines equally, will raise the voltage of the telephone line and telephone transformer to a value sufficient to break down the air gap to ground and will not impress any high voltage across the terminals of the telephone transformer unless the ground gaps are set unequally, in which case the gap with the smallest setting will drain the wire connected to it directly and will drain the wire with the larger gap setting through the vacuum tube arrester.

If the voltage is impressed unequally on the telephone lines, the vacuum gap will spark across, holding the voltage across the terminals of the telephone transformer and the telephone to a safe, low value.

The choke coils are used to retard steep wave front impulses until the arrester gaps will have time to discharge.

It has been found that a continuous discharge through the vacuum gap will melt the solder and compound used to seal the case of the vacuum tube, allowing the vacuum to be des-

troyed. The cylinder gap connected in parallel with the vacuum gap is for the purpose of holding the line to line voltage as low as possible in case the vacuum gap is destroyed. The lowest advisable setting on these cylinders will give an arcing voltage in the air of approximately 700 volts and the cylinder gap will never come into play unless the vacuum gap has been destroyed.

The expulsion fuses used are of five-ampere capacity and will not blow unless there is a very severe disturbance on the telephone line. The five-ampere fuse was selected because we did not wish to use a fuse large enough to cause burning of the vacuum gap or the cylinder gaps or to use a fuse so small that it would blow on slight disturbances.

A test was made on this lightning arrester by taking 50,000 volts from a power line supplied from a 550-kw. generator, the power line being connected from line to line on the telephone arrester, from each line to ground and both lines in parallel to ground. Eight tests were made on one arrester with this 50,000-volt power supply, with a telephone transformer and telephone connected during the tests.

Tests were also made in the lightning arrester laboratory of the General Electric Company on oscillation transformers of 200,000 and 500,000 cycles with oscillating circuits adjusted for voltages from 50,000 to 150,000 volts. An arrester unit was connected in parallel and in series with the main sphere gaps and a number of shots were made. After the completion of the tests the telephone transformer and telephone were still in good condition.

A number of small arresters with the same essential arrangement of the arrester parts have been used on telephone lines paralleling 11,000 and 22,000—volt lines around Atlanta. Some of these arresters have seen about two years service.

A large number of severe lightning disturbances have been handled by these arresters and in one case the 22,000-volt power line fell on the telephone line immediately after the lightning stroke. The main wires to the arrester and the ground wires on the arresters at both ends of the lines were burned off and in this case as well as in all other cases no damage has been done to the telephone transformer or to the telephone. In the same territory a very large number of telephone transformers and telephones have been destroyed by lightning although they were protected by the best arrester system which we had been able to obtain from the manufacturers.

Test of Telephone Lightning Arrester to be Used on Telephone Lines Adjacent to 110,000-Volt Power Lines

One 555-kw., 440-volt, 60-cycle alternator was connected to a 625-kw., 440 to 50,000-volt transformer and the high side of the transformer used on the arrester tests. On these tests the circuit breaker of the transformer bank was set at 1600 amperes, the normal load on one generator being 625 amperes.

Test No. 1. Referring to the diagram on a preceding page, the horn gaps at the top were not used.

Line No. 1 was connected to one transformer terminal and line No. 2 was connected to the other transformer terminal. The generator was adjusted to give 50,000 volts and the circuit breaker closed, giving 50,000 volts directly on the telephone lightning arrester. On this test the cylinder gaps and the vacuum gap on the main line arced across blowing the main line fuses.

Test No. 2. Same as test No. 1.

Test No. 3. Lines No. 1 and No. 2 were tied together and connected to one power transformer terminal and the leads marked ground were connected to the other transformer terminal. When 50,000 volts was applied the spark gaps arced across, blowing the primary fuses.

Test No. 4. Same as No. 3.

Tests No. 5 and No. 6. Line No. 2 was connected to one power transformer terminal and ground gap connected to the other power transformer terminal. 50,000 volts was applied, blowing the primary fuses.

Tests No. 7 and No. 8. Line No. 1 was connected to one power transformer terminal and the ground gap connected to the other power transformer terminal. 50,000 volts was applied, blowing the primary fuses.

After each of the above tests the 1 to 1 transformer and the telephone bell were tested and found OK. The vacuum gap connected on the high side of the 1 to 1 transformer broke down at 360 volts before the high voltage tests were made and broke down at 370 volts after tests were made.

It is of interest to note that the arrester on the low side of the telephone transformer never had its fuses blown, showing that all high voltage strains were relieved before they reached the telephone transformer.

This test corresponds very closely to the condition which will obtain when one of the 110,000-volt power lines crosses with

either or both of the telephone lines. In this case the voltage will be 63,500 volts while the voltage on the tests was 50,000. However in service, 63,500 volts can never reach the telephone lightning arrester because the insulators on the telephone line will arc across at much lower voltage than this.

PRESERVATIVES FOR WOOD CONSTRUCTION (QUESTION G-1-2)

The following information is received as to preservative treatment of wood poles:

The following companies treat wooden pole butts—either by brushing or open tank treatment using carbolineum, hot gas drippings, creosote oil, or hot tar.

Miss. P. (cost 10 cents per pole), for brush treatment only.

Gt. Wn. P.

Ap. P.

Sou. S. P. Open tank process.

Wash. W. P. Carbolineum oil on cedar poles; two feet above and below ground line. Tamarack poles treated by charring 6 ft. below ground line and pouring hot carbolineum oil over charred surface. Cost 25 cents per pole.

San J. L. & P. Open tank process; average penetration 5/8 in. for 8 ft. on butt; cost approx. $1.50 per 50 ft. pole.

Niag. L. & O. P.

Ch'a V. R. L. & P. Open tank; cost 40 cents to $1.50.

Ut. L. & R. Cost one quart carbolineum and 10 cents labor per pole.

Mt. Wh. P. & E. Paint poles; cost 50 cents per pole.

Un. T.

TREATING CROSSARMS (QUESTIONS G-3-4)

The following companies treat crossarms and pins as specified:

Yad. R. P. Crossarms and pins, open tank, four hours in oil 100 deg. cent. 4 hours in cold oil.

Ap. P. Crossarms same as butts.

Sou. S. P. Crossarms and pins same as butts.

San J. L. & P. Crossarms given two coats of good paint.

Niag. L. & O. P. Crossarms creosoted in open tanks or treated with avenarius carbolineum.

Port. R. L. & P. Crossarms dipped in preservative.

Ch'a V. R. L. & P. Crossarms brush treated.

Ut. L. & P. Crossarms, paint and oil; pins paraffin.

C. N. P. Pins on new line impregnated with Bakelite.

Mt. Wh. P. & E. Pins boiled in linseed oil.

Un. T. Crossarms and pins—open tank creosote treatment.

Cty. S. L. Dpt. Boiled in carbolineum.

Gain in Life by Treatment (Question G-5)

With regard to the gain in life from treatment note the following:

Gt. Wn. P. No deterioration as yet.

Sou. S. P. 5 to 10 years, based on older Col-Nevada Power Co. System.

San. J. L. & P. Creosoted butts have lasted 6 years on pine poles, that would otherwise decay in 16 months. We have only been treating pole butts for 6 years, but our experience shows the protection afforded is well worth the cost. Our principal pole timber is Washington red cedar.

By creosoting butts and properly painting crossarms, the wooden pole line should have a life of at least 25 years. We have a square sawed redwood line, carrying six No. 3 copper conductors at 30,000 volts (and a portion of the time 60,000 volts) 35 miles long. This was built 8 years ago and pole butts were *not* treated. Recent patrol and inspection showed 70 per cent of poles perfectly sound above and below ground.

Niag. L. & O. P. Crossarms in good condition; poles show various amounts of decay at ground line.

Port. R. L. & P. Poles last 12 to 15 years without treatment and under favorable conditions treatment may add two or three years to life of pole.

Ch'a V. R. L. & P. Life of poles has been increased.

Ut. L. & R. 10 years in dry climate.

Cty S. L. Dpt. Crossarms 12 years old show no depreciation.

Outdoor Oil Apparatus (Question H-4)

As to the general satisfaction with outdoor transformers, oil switches and subsations, note the following:

Miss. P. Satisfactory.

Yad. R. P. Satisfactory, are using them exclusively in high tension work.

Ap. P. Yes.

Sou. S. P. Outdoor stations on transmission line serve as switching stations as well as transforming stations. Two switches are cut into each of these two lines passing through the station and a paralleling set of disconnecting switches for lines. Steel is used throughout for the supporting structures. Transformers

are all provided with trucks and each station has a transfer track and truck for moving transformers into a building which contains a pit and lifting rig and also serves as a storeroom for supplies and repairs. We have every reason to be pleased with the outdoor type station of this character.

Wash. W. P. Cheaper and satisfactory.

San J. L. & P. We place station transformers on separate foundations, about 35 ft. apart. Poles are placed directly back of each transformer, to which are attached by strain insulators, the high-tension and low-tension leads to the switch house. The switching house protects both high-tension and low-tension switches and metering equipment. This house is usually a frame structure covered with galvanized iron. Current transformers are installed indoors and potential transformers on poles outside. These stations have proved very satisfactory.

Niag. L. & O. P. Westinghouse outdoor type GA, oil circuit breaker satisfactory.

Ch'a V. R. L. & P. All standard and entirely satisfactory.

Mt. Wh'y P. & E. Yes.

Cty. S. L. Dpt. Outdoor bushings all right on electrolytic lightning arresters.

Use of Breathers (Question H-5)

Most companies report that they do not use breathers in outdoor transformers but the following may be noted:

Yad. R. P. Use chloride of lime breathers but do not consider them necessary.

Mt. Wh'y P. & E. Yes, no trouble so far—use inverted elbow and fine mesh screen.

Penetration of Water in Outdoor Transformers (Question H-6)

Most companies report that no water penetrated weatherproof tanks, but note—

Yad. R. P. Not when in operation and temperature high.

San J. L. & P. In some of smaller sizes of transformers (100 kw.) moisture has penetrated the tanks. However, other installations of exactly similar make and capacity gave no trouble.

Outdoor Type High-Tension Bushings in Wet Weather (Question H-7)

Most companies report that out door type bushings operate satisfactorily in wet weather and none report trouble.

Corona (Question H-13)

No plant has observed any corona except *Miss. P.*, which gave a curve of corona losses reproduced in the drawing, Fig. 57.

General

Pa. W. P. Note the following general comments:

Some of the changes which we have made, or contemplate making, in our equipment may be of interest as indicating the lines along which our operating experience and experiments are leading us.

A duplicate 11,000-volt generating station bus system was installed to replace the original group single bus system. This change made it easier to inspect and clean busses and connections, and made possible a better grouping of apparatus and reactances to limit short circuit rush of current.

Reactances were installed between busses and transformers, and in sections of the busses. These reactances were rendered necessary by reason of the concentration of generating apparatus, giving peaks of over 70,000 kw. all of which power was sent over two transmission circuits to Baltimore. The destructive effects of short circuits, backed by such large generator capacity were becoming serious.

Nicholson arresters and field destroying devices were installed and a *fused air gap* arranged for the generating station to take a portion of these *heavy lightning discharges* which are *too great* for the *electrolytic arresters* to take care of. The Tirril regulator equipment was abandoned and a storage battery with Keilholtz-Ricketts booster regulating system installed.

During the first period of operation the relay system was based upon the use of inverse time-element, reverse power, and definite time-element relays, set progressively higher in time from substation to power house. A great deal of experimental work, both in the laboratory and under operating conditions, was done in connection with the development of more accurate relays, but the results were not satisfactory. For a time, a modified Mertz-Price system was considered and partially installed, but was later abandoned for the system at present in use, which gives immensely superior results over the previous systems. With a steady increase of generator capacity concentrated on a few circuits, the destructive effects of arcs are becoming greater, so that a short circuit, which previously, with a small generator capacity, could have been allowed to remain on for six or seven

seconds, now does too much damage in that time in the way of melting of conductors, etc., so that our experiments are now along the line of cutting down the length of time which a short circuit remains upon the system.

We attribute our freedom from sleet disturbances to the very heavy mechanical construction employed and the frequent spacing of anchor towers.

We are now building a second tower line to Baltimore on the same 100 ft. right of way strip, 50 ft. distant from the first tower line. The second tower line has the following improvements: the number of members to a tower is less than previously, decreasing handling, erection and inspection costs, and making possible a minimum thickness of material of 3/16 in. as against a previous minimum of 1/8 in. All bolts are 5/8 in. diameter as against ½ in. diameter for the previous towers; the smaller bolts are very likely to be overstressed in tightening. The middle crossarm of the new line is being lengthened so that the top and bottom conductors of a circuit will be in the same vertical plane while the middle conductor will be further away from the tower.

This is to take care of unequal sags due to unequal sleet loading. Such unequal sleet loading has actually been observed on our lines and was anticipated in the design of the first line, but so far the unequal loading has not been sufficient to interfere with service. The distance between the crossarm and the conductor just above was such that on the old line buzzards when raising their wings to fly would ground the circuit; in the new line, a greater distance between crossarm and conductor above has been arranged for. In the first line steel tripod foundation stubs were used for the suspension towers; in the new line, all foundation stubs are of concrete. Interchangeability of bolts and certain members has been provided for in the new towers, which makes easier work of erection of the towers in the way of distribution of material and assembly.

In the first line as originally built there was a very considerable arcing over of the insulators due to lightning. A very complete record was kept covering the location of the disturbances, the phases upon which disturbances occurred, insulators cracked, etc. During the following year additional insulator units were added on one circuit over those two sections of the transmission line which had suffered most the previous year and a careful record again kept of the effect of lightning. These records indicated that there were no spill-overs during the second year on those

sections where additional insulator units had been cut in, except in one case where the discharge had jumped from conductor to crossarm below; this clearance distance having been decreased by the additional insulator units. Then additional strain and suspension insulator units were cut in on both circuits, so that at present No. 1 circuit has seven instead of five insulator units and eight instead of six strain units. Circuit No. 2 has six instead of five insulator units and seven instead of six strain units. The improvement, as regards lessened lightning spillovers, during the time the more heavily reinforced lines have been in service has been marked.

The first transmission line was equipped with a single ground wire. Our experience has not indicated that this ground wire has been of any benefit in preventing disturbances. In order to establish the matter a little more definitely, the new transmission line is being equipped with two ground wires placed above and outside of the upper power conductors. The ground wire on the first line was originally strung so tight as to cause considerable trembling of the towers and it was necessary to cut in additional ground wire to increase the ground wire sag. This was done during operation without interfering with service.

Drawings

The following cuts are reproduced from drawings, charts and photographs submitted by the various reporting companies. In most cases the drawings have been redrawn to eliminate unnecessary detail and to consolidate the useful information embodied. The significance of each drawing may be obtained from its title, combined with the legends or other information on the face of the drawing. In all cases except one the name of the company furnishing the information is noted.

A number of valuable maps, charts, and photographs were received which could not be readily reproduced. These are open to the inspection of members of the Institute at New York headquarters. The Secretary will, where feasible, furnish copies for cost* on application. A list of some of the more valuable matter not reproduced follows:

Geographical Maps. Gt. Wn. P.; Yad. R. P.; Mex. L. & P., Ap.. P. Sou. S. P.; Niag. L. & O. P.; Port. R. L. & P.; Mt. Wh'y P. & E.; X·

*In case of blue prints retracing will generally be necessary.

Line Circuit Diagrams. *Mex. L. & P.; *Pa. W. & P.; *Niag. L &; O. P.; W'n Sts. G. & E.; C. N. P.; Mt. Wh'y P. & E., *Pug. S. T. L. & P.

Design Drawings of Steel Towers with Details. Miss. R. P.; Yad. R. P.; Niag. L. & O. P. (pipe towers); C. N. P. (pipe towers).

Detail Drawings of Wood Pole Construction. Niag. L. & O. P. (pin details of A frame top); Wash. W. P. (Two pole braced "bridge" construction, 2 types one circuit line with one ground wire, 2 types one circuit line with no ground wire, angle towers with grounded wire guards); also W'n St's G. & E.; Pug. S. T. R. & P., (A frame pole and pole-top switch); and X.

Miss. R. P. Tower foundation drawing.

Wash. W. P. Details of telephone line transposition. Detail of cable clamps and usual attachments for suspension insulators; wrought iron pin; details of extension of middle cross arm on steel towers added after erection.

Port. R. L. & P. Details of "jumper" at strain pole and insulator attachment; detail of outlet and the first span of the line at power house.

Niag. L. & O. P. Detail arrangement of room with transformers electrolytic arresters and wiring.

Mt. Wh'y G. & E. Details of 33,000 and 6,600-volt telephone and railway crossing.

ENGINEERING DATA SUB-COMMITTEE

PERCY H. THOMAS, *Chairman.*

W. A. CARLE	C. S. MCDOWELL
F. F. FOWLE	HAROLD PENDER
H. M. HOBART	E. B. ROSA
L. E. IMLAY	W. S. RUGG
O. A. KENYON	C. E. SKINNER
A. S. MCALLISTER	C. W. STONE

*Showing sectionalizing of busbars, types and locations of circuit breakers, etc.

VI	Special Structures	.07% of VII	96 748	Mi. L. Tower	24.50 3.03			$2,256	Includes Sanford Sect onalizing Tower.
A	Telephone & Highway Prot.	5.4% of VI	5	Each	24.20		122		Temporary Labor at R. R. crossings.
B	Miscellaneous	45.5% " "	21	"			1,028		Disconnecting switches and labor.
C	Sectionalizing Tower	49.1% " "	1	"			1,106		Special Tower at Sanford.
1	Contract Price Delivered		1	"		565			
2	Handling & Hauling		1	"		6			
3	Erecting		1	"		118			
4	Assembling		1	"		151			
5	Digging Holes		8	Hole	2.12	17			
6	Wire Installation		1	Each		249			
VII	Total Material & Labor	100%	96 748	Mi. L. Tower	$3235 415			$310,738	70.2% of Total Cost.
VIII	Surveying	1.8% of VII	96	Mi. L.	59.25			$5,691	Does not include cost of original survey made by Lockwood, Greene & Co.
A	Salaries	48.6% " VIII	"	"	28.80		2,767		
B	Tra ing Expenses	12.6% " "	"	"	7.49		719		
C	Equipment	5.5% " "	"	"	3.24		311		
D	Miscellaneous Supplies	0.5% " "	"	"	.27		26		
E	" Expense	0.3% " "	"	"	.17		16		
F	Telephone Line	32.5% " "	102	"	18.18		1,852		
IX	Right-of-Way	12.7% of I-VIII	96	Mi. L.	418.89			$40,214	50′ Right-of-Way—Practically none donated.
A	Agent	7.7% " IX	"	"	32.30		3,103		Portions of Right-of-Way—Practically 100′, & ab. 1 mil 30′
1	Salaries		"	"	22.30	2,140			From Blewett Falls to Method 1072 acres avg. cost per acre for easements $10.30;
2	Traveling Expenses		"	"	8.89	853			
3	Miscellaneous		"	"	1.11	110			
B	Legal Expenses	5.4% of IX	"	"	22.40		2,151		From Method to So. Power Tie 100 acres avg. cost per acre for easements $23.37. Avg. purchase cost over total line—$11.42 per acre.
1	Salaries		96	Mi. L.	7.60	730			
2	Traveling Expenses		"	"	14.80	1,421			
C	Purchase-Price-Easements	33.2% of IX	"	"	139.40		13,382		
D	Damages	2.5% " "	"	"	10.32		993		
E	Clearing	22.8% " "	"	"	95.55		9,177		About 30% clearing heavy & swampy.
F	Telephone Line	28.4% " "	102	"	118.80		11,408		Includes $1620. for clearing.
X	Construction Equip't.	3.2% of I-IX	96	Mi. L.	119.20			$11,443	Net C[illegible]

	A		Wagons & Horses	22.7% of X	"	"	27.10		2,601	[illegible]	Net Cost.
	B		Tents & Camp Equip.	24.9% " "	"	"	29.62		2,844		Depreciation
	C		Rigging & Tools	20.4% " "	"	"	24.30		2,333		"
	D		Moving Camp	22.6% " "	"	"	27.00		2,590		"
	E		Roads	2.3% " "	"	"	2.68		258		
	F		Charges To Tel. Line	7.1% " "	102	"	8.02		817		Depreciation
XI			Commissary & Stores	4.2% of I-X	96	Mi. L.	160.00			$15,384	Net Cost.
	A		Board & Lodging	65.9% " XI					10,137		
		1	Supplies					11,559			
		2	Labor					5,765			
		3	Outside Board					604			
		4	Credits					(7791)			
	B		Commisary Operation	10.9% of XI					1,671		
		1	Supplies					3,093			
		2	Labor					445			
		3	Credits					(1867)			
	C		Charged to Tel. Line	23.2% of XI					3,576		
XII			General Expense	7.1% of I-XI	96	Mi. L.	284.70			$27,375	
	A		Salaries	48.1% " XII					13,173		
	B		Traveling Expenses	7.8% " "					2,133		
	C		Office Rent	0.3% " "					75		
	D		" Equipment	2.7% " "					747		
	E		Telephone & Telegraph	2.2% " "					594		
	F		Liability & Injuries	4.4% " "					1,214		
	G		Livery	4.0% " "					1,090		
	H		Automobile	4.8% " "					1,300		
	I		Transfer & Employ. Labor	5.2% " "					1,423		
	J		Charged to Tel. Line	20.2% " "					5,520		
	K		Miscellaneous	0.3% " "					106		
XIII			Contingencies	0.2% of I-XII	96	Mi. L.	6.98			$670	Labor & Matl. Re-erecting towers damaged by wind.
XIV			**Engineering**	5.4% of I-XIII	96	Mi. L.	229.50			$22,014	
XV			**Interest During Constr.**	2.1% of I-XIV	96	"	96.50			9,271	
XVI			**Total Cost**		96 748	" Tower	4613. 591.			$442,800	

[Face p. 1488]

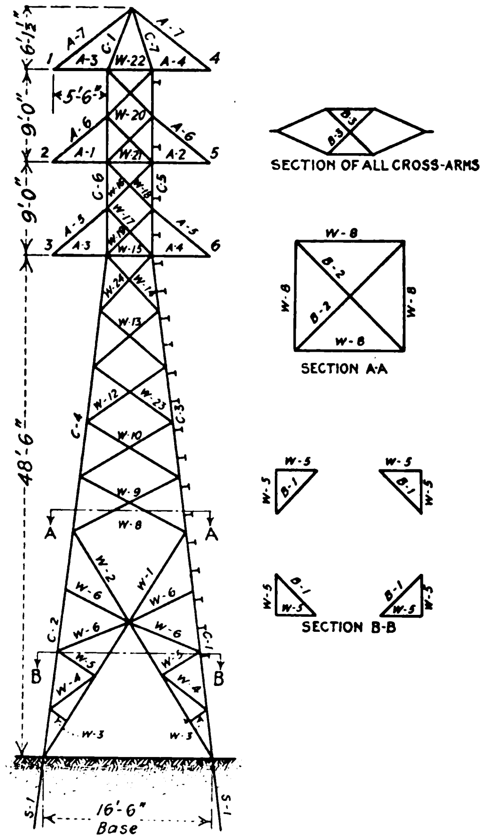


FIG. 1—YAKDIN RIVER POWER CO.—STANDARD DOUBLE CIRCUIT TRANSMISSION TOWER FOR 100-KV. LINES

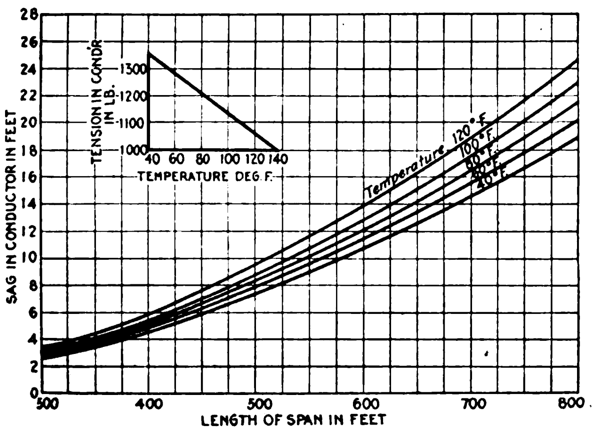


FIG. 2—YADKIN RIVER POWER CO.—SAG AND TENSION CURVES FOR No. O. B. & S. COPPER STRAND.

NOTE:—Maximum strain 25,000 lbs. per sq. in. at 0 deg. fahr. ½ in. sleet, 50 mi. per hr. wind

LIST OF MATERIAL FOR ONE COMPLETE TOWER. (See Fig 1).

No.	Shape	Size	Length Ft.	Length In.	Mark	Remarks	Weight in Lb.
1	L	3 x 3 x 3/16"	27-	8 5/16	C-1		102.7
3	L⁵	3 x 3 x 3/16	27-	8 5/16	C-2		308.2
1	L	2¾ x 2¾ x 3-16	21-	10	C-3		74.0
3	L⁵	2¾ x 2¾ x 3-16	21-	10	C-4		222.0
1	L	2½ x 2½ x 1/8	18-	8 3/16	C-5		38.8
3	L⁵	2½ x 2½ x 1/8	18-	8 3/16	C-6		116.6
4	L⁵	2½ x 2½ x 1/8	6-	8 1/8	C-7		55.6
2	L⁵	2½ x 2½ x 1/8	6-	4½	A-1		26.5
2	L⁵	2½ x 2½ x 1/8	6-	4½	A-2		26.5
4	L⁵	2½ x 2½ x 1/8	6-	4½	A-3		53.0
4	L⁵	2½ x 2½ x 1/8	6-	4½	A-4		53.0
4	Flats	1¼ x 3/16	7-	5 9/16	A-5		23.8
4	Flats	1¼ x 3/16	7-	6 3/8	A-6		24.0
4	Flats	1¼ x 3/16	9-	4¾	A-7		30.0
6	T⁵	4½ x 3 x 8.4	0	5 3/16	A-8		21.8
4	L⁵	1½ x 1½ x 1/8	25	5 7/8	W-1		125.4
4	L⁵	1½ x 1½ x 1/8	25	5 7/8	W-2		125.4
8	L⁵	1¼ x 1¼ x 1/8	2	4½	W-3		19.2
8	L⁵	1¼ x 1¼ x 1/8	5	7 3/8	W-4		45.3
8	L⁵	1¼ x 1¼ x 1/8	4	8 3/8	W-5		37.9
16	L⁵	1¼ x 1¼ x 1/8	7	0 3/8	W-6		113.6
4	L⁵	2¾ x 2¾ x 1/8	10	11¾	W-8		100.5
8	L⁵	1½ x 1½ x 1/8	11	8 9/16	W-9		115.2
8	L⁵	1½ x 1½ x 1/8	10	3 15/16	W-10		101.6
4	L⁵	1½ x 1½ x 1/8	9	4 9/16	W-11		46.1
2	L⁵	2½ x 2½ x 3/16	9	4 9/16	W-12		57.6
8	L⁵	1½ x 1½ x 1/8	8	4 1/16	W-13		82.0
6	L⁵	1¾ x 1¾ x 1/8	7	4 5/8	W-14		63.8
4	L⁵	2 x 2 x 1/8	4	5	W-15		29.1
4	L⁵	1¾ x 1¾ x 1/8	6	2 31/32	W-16		36.0
4	L⁵	1¾ x 1¾ x 1/8	6	2 31/32	W-17		36.0
4	L⁵	1¾ x 1¾ x 1/8	6	2 31/32	W-18		36.0
4	L⁵	1¾ x 1¾ x 1/8	6	2 31/32	W-19		36.0
16	L⁵	1¼ x 1¼ x 1/8	6	2 1/8	W-20		99.8
2	L⁵	2 x 2 x 1/8	4	5	W-21		14.6
2	L⁵	2 x 2 x 1/8	4	5	W-22		14.6
4	L⁵	1½ x 1½ x 1/8	4	3¾	W-23		21.2
4	L⁵	1¼ x 1¼ x 1/8	6	1½	B-1		24.7
2	Flats	1¼ x 3/16	15	8 9/16	B-2		24.9
6	Flats	1¼ x 3/16	6	2¾	B- 3		29.8
38	B. H. St	ep Blts ⅝"φ	0	5 1/8	Hex. Nu	t 1¾"Thrd	16.9
38	Pieces ½"	φ Gas Pipe.	0	4	Ends Sq	uare	10.6
38	Washers	1 3/8" φ	9/16"	φ Hole	No. 12 G	auge	1.9
390	Bolts ⅝"	φ 1½" Lnd.	¾"	Min. Gr	ip Sq. Hd	. Hex. Nut.	6.8
4	Bolts ⅝"	φ 2"	Lng.	7/8 M	in. Grip	Sq. Hd He	x Nut .9
1	Ground	Wire Clamp					7.4
2	L⁵	1¾ x 1¾ x 1/8	7	4 5/8	W-24		21.3
2	L⁵	2½ x 2½ x 3/16	9	4 9/16	W-25		57.6
6	Insulator	Hooks					8.7
		Total	Net W	eight of	one Stan	dard Tower	2814.9
4	L⁵	3 x 3 x ⅜"	8	0	S-1		156.8
4	C⁵	12"-20½"	1	6	S-2		123.0
8	Pls.	8 x ½	0	2	S-3		16.4
						Grand Tot	al 3111.1

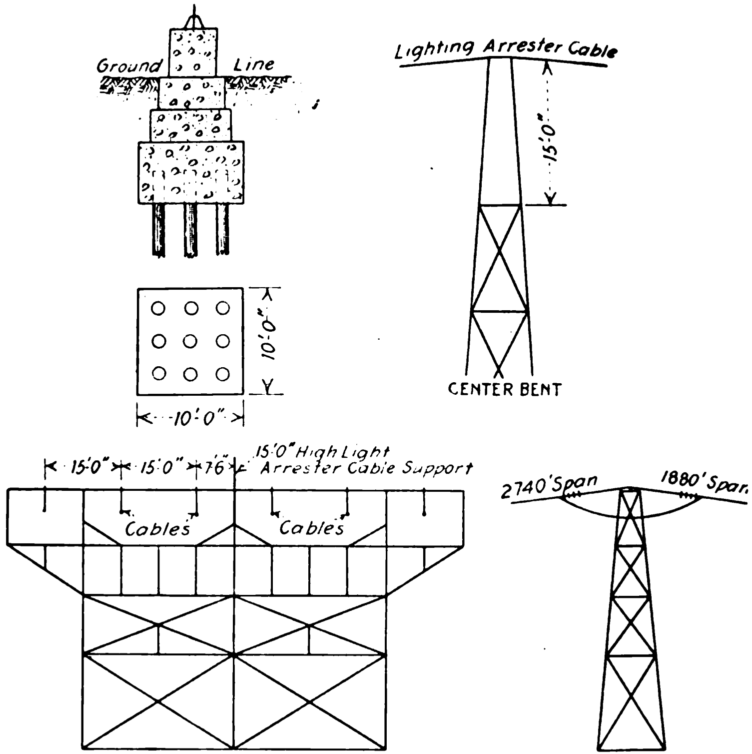


FIG. 3—GREAT WESTERN POWER CO.—TOP OF SPECIAL TOWER AT WEST ISLAND

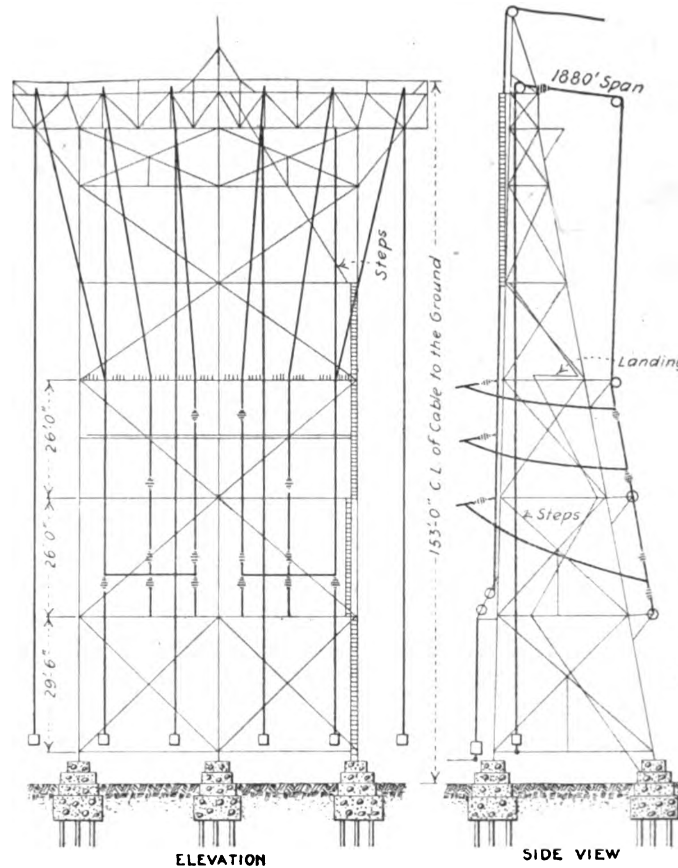


FIG. 4—GREAT WESTERN POWER CO.—SPECIAL TOWER AT KELLY ISLAND

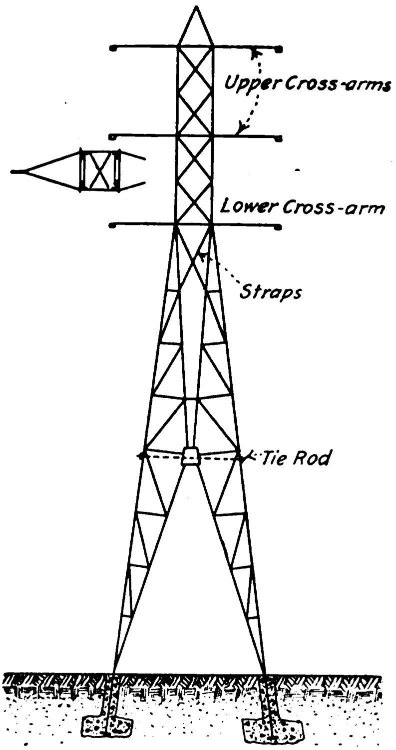


FIG 5—GREAT WESTERN POWER CO.—SKETCH OF STANDARD TOWER

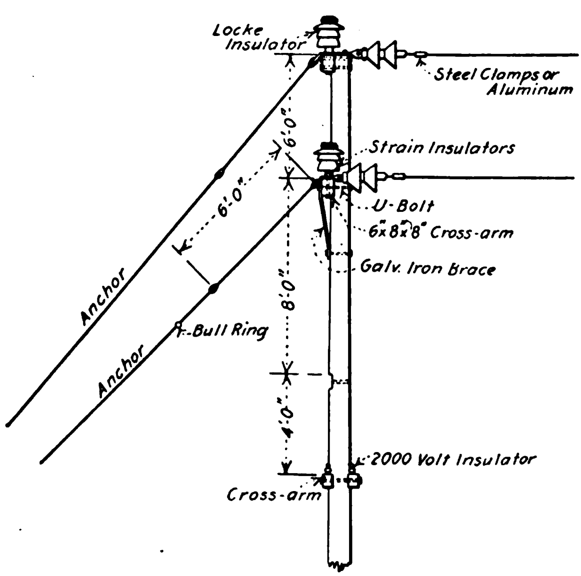


FIG. 6—SAN JOAQUIN LIGHT AND POWER CORPORATION. DETAILS OF ANCHORED POLE

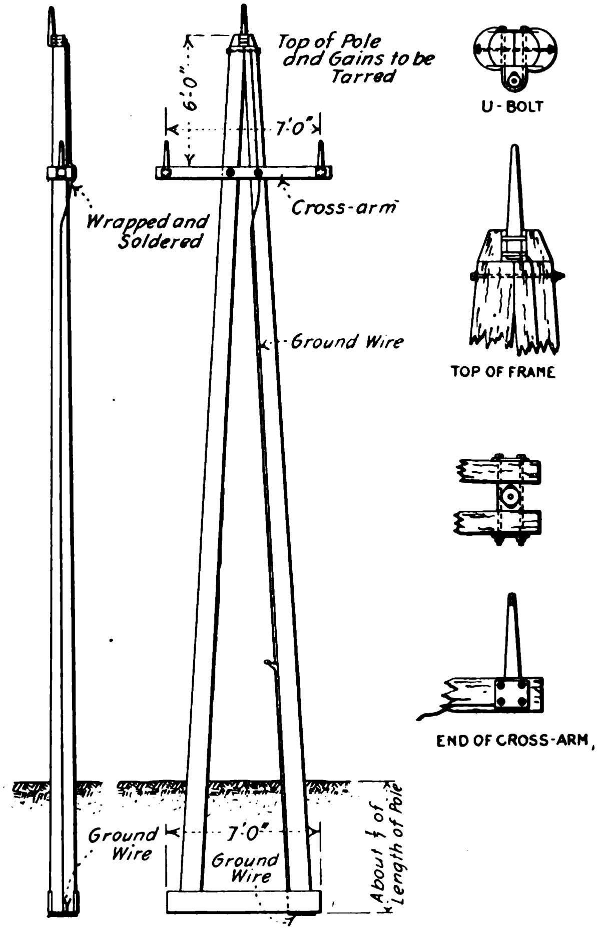


FIG 7—NIAGARA, LOCKPORT AND ONTARIO POWER COMPANY COMPANY.
STANDARD A-FRAME STRUCTURE.

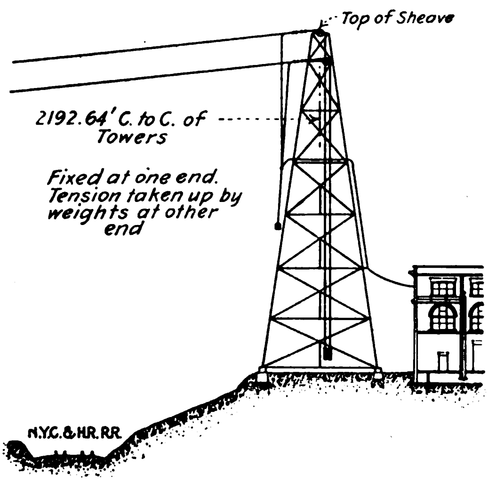


FIG. 8—CANADIAN NIAGARA POWER CO. TOWER AT NIAGARA CROSSING

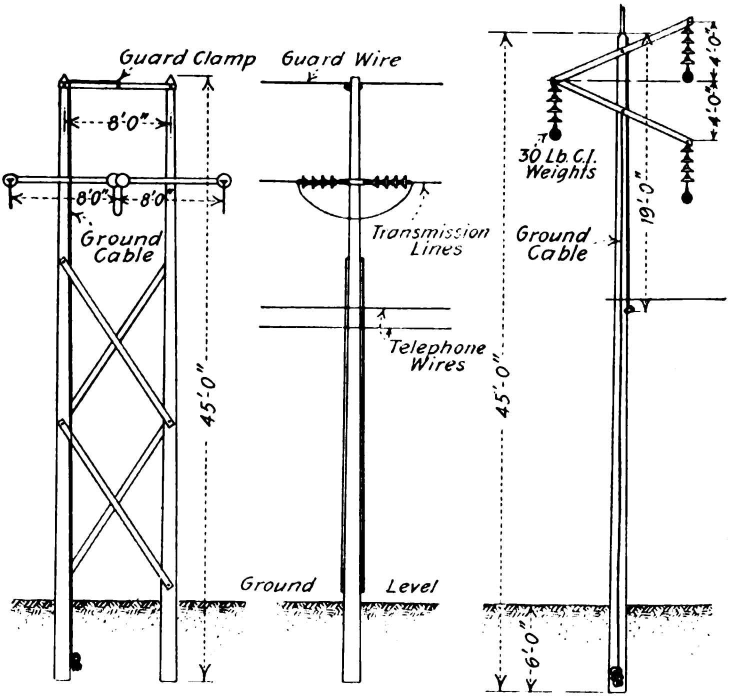
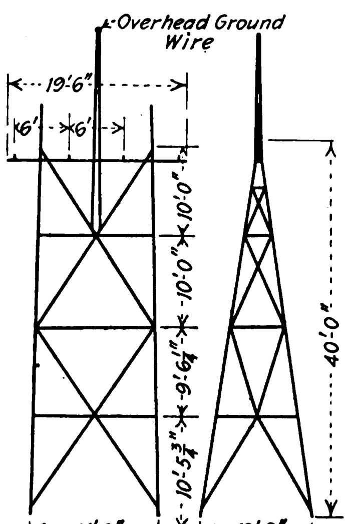
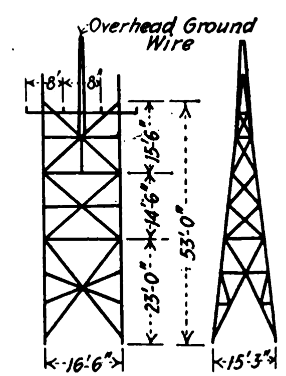


FIG. 9—APPALACHIAN POWER CO. POLE LINE CONSTRUCTION STANDARDS



Std 40 ft. Tower. Present Line. Span-400 ft.

FIG. 10—TORONTO POWER CO.



Std. 53 ft. Tower New Line. for 650 ft. Span

FIG. 11—TORONTO POWER CO.

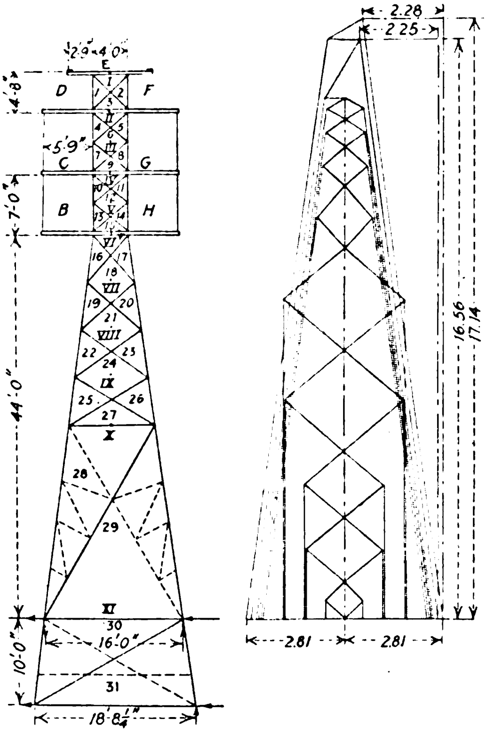


FIG. 12—PENNSYLVANIA WATER AND POWER CO. DETAILS OF TOWER.

	Load from wire	Wind pressure	Total Load
I	1.9	0.22	2.12
II	1.9	0.43	2.33
III		0.14	0.14
IV	1.9	0.42	2.32
V		0.14	0.14
VI	1.9	0.47	2.37
VII		0.22	0.22
VIII		0.23	0.23
IX		0.25	0.25
X		0.49	0.49
XI		0.64	0.64

Wind pressure = 13 lb. per sq. foot.

Location	Load	Load per. sq. inch.	Section	Area	Ultimate Strength	Factor of Safety
H-11	6.28	5.65	3" x 3" x 3/16"	1.11	39.86	7.
H-14	9.15	8.25	" " "	"	"	4¾"
I-20	14.08	5.85	4" x 4" x 5/16"	2.41	35.92	6
I-23	15.04	6.25	" " "	"	"	5¾
I-26	15.94	6.62	" " "	"	"	5½
I-29	10.2	6.36	4" x 4" x 3/8"	2.86	35.51	5½
15-17	1.18	2.36	2" x 2" x ¼"	.50	13.27	5½
18-20	.85	6.70	" " "	.50	10.92	6½
21-23	.69	.38	" " "	.50	9.00	6½
24-26	.60	1.20	" " "	.50	5.85	5
I-31	19.15	6.70	4" x 4" x 3/8	2.86	32.51	5

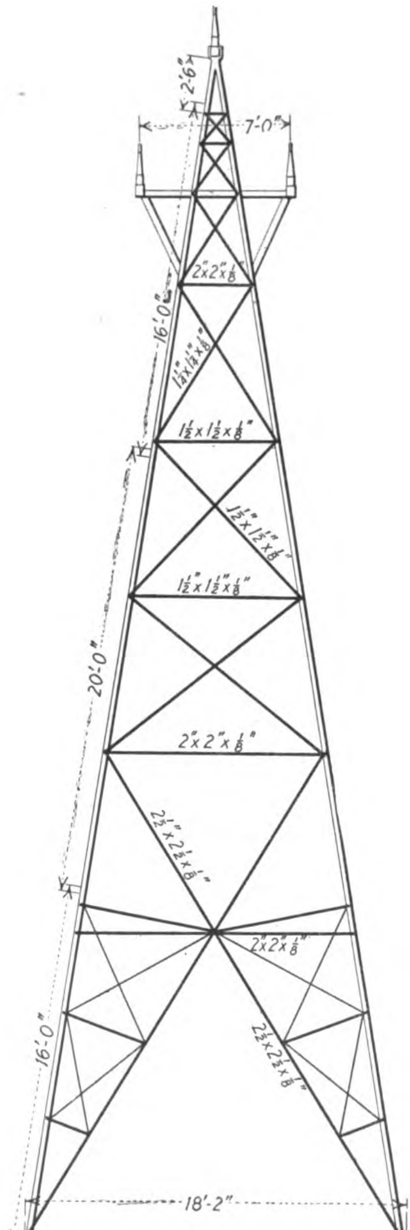


FIG. 13—NIAGARA, LOCKPORT AND ONTARIO POWER CO. 49-FOOT SINGLE AND DOUBLE PIN TOWER

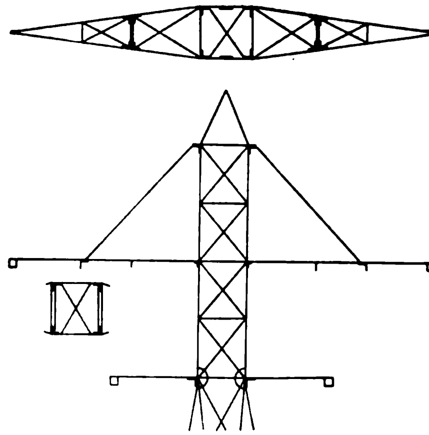


FIG. 14—GREAT WESTERN POWER CO. SKETCH OF TOP OF REINFORCED TRANSPOSITION TOWER.

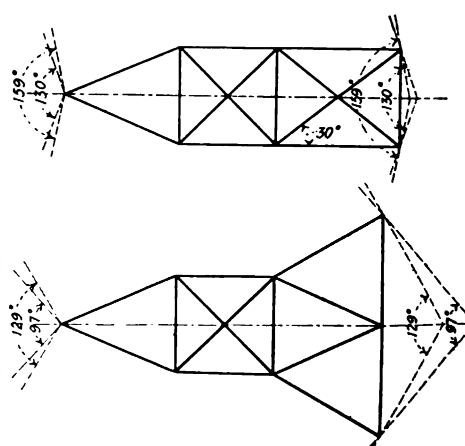


FIG. 15—MISSISSIPPI RIVER POWER CO. SPECIAL CROSSARMS FOR ANGLE TOWER

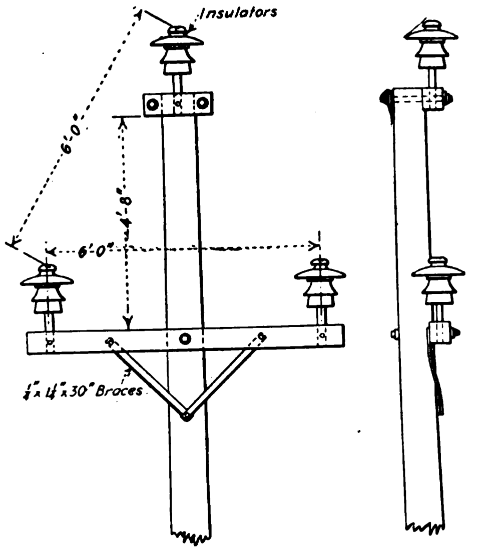


FIG. 16—WESTERN STATES GAS AND ELECTRIC CO. TRIANGULAR CONSTRUCTION OF 60,000-VOLT TRANSMISSION LINE.

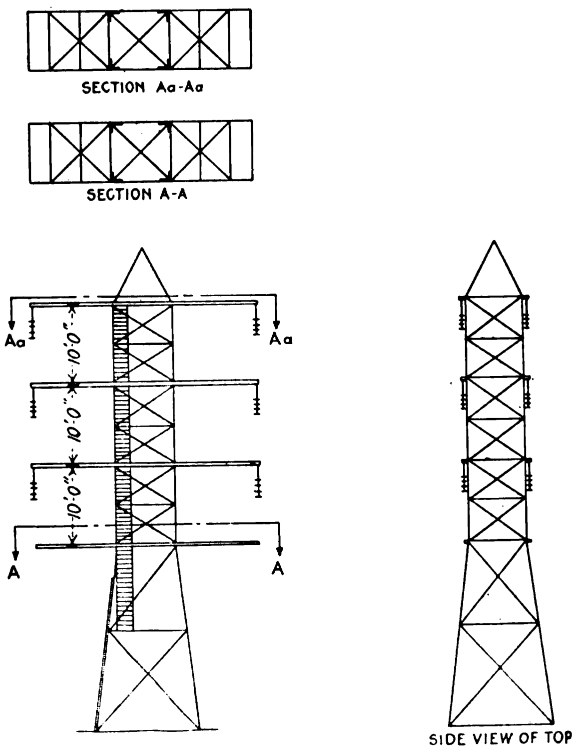


FIG. 17—GREAT WESTERN POWER CO. TOPS OF TWO SPECIAL TOWERS AT ISLE TON

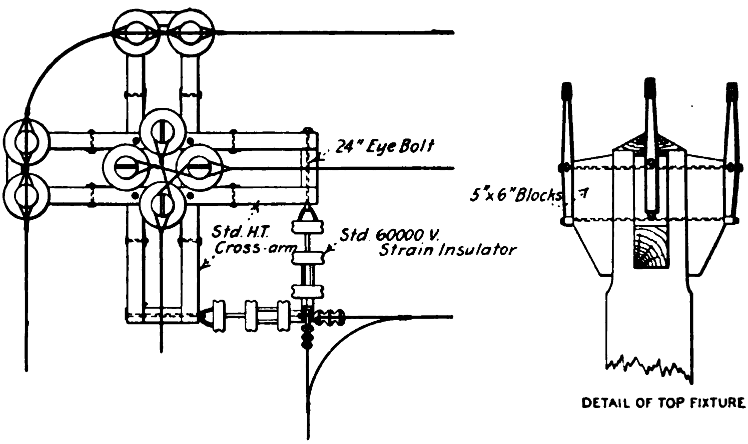


FIG. 18—PUGET SOUND TRACTION LIGHT AND POWER CO. SQUARE TURN ON 60,000-VOLT LINE CONSTRUCTION

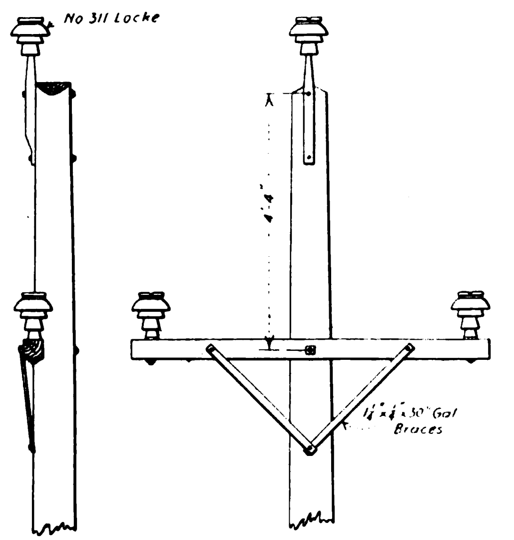


FIG. 19—MT. WHITNEY POWER AND ELECTRIC CO. STANDARD CONSTRUCTION FOR 35,000 VOLTS

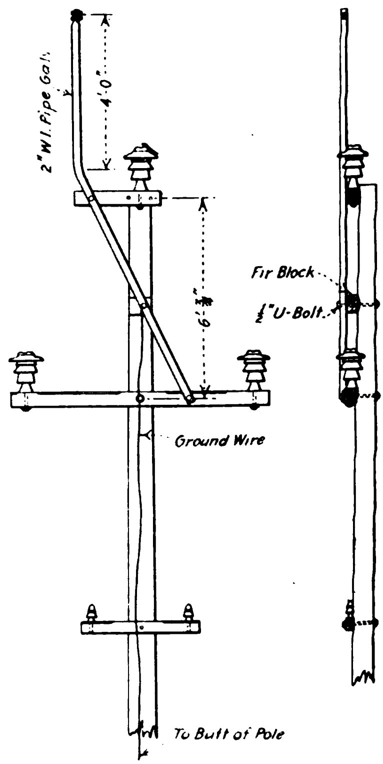


FIG. 20—THE WASHINGTON WATER POWER CO. OVERHEAD GROUND WIRE SUPPORT, ODESSA TRANSMISSION LINE

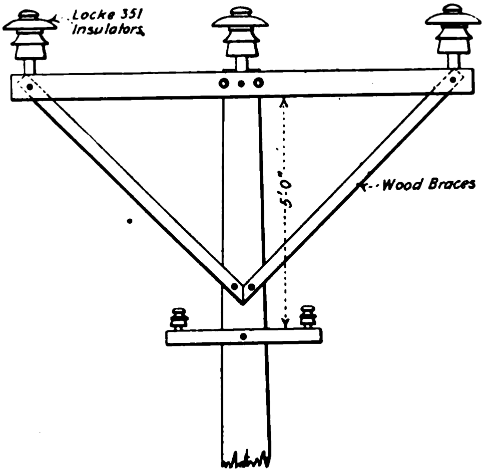


FIG. 21—WESTERN STATES GAS AND ELECTRIC CO. FLAT CONSTRUCTION OF 60,000-VOLT TRANSMISSION LINE.

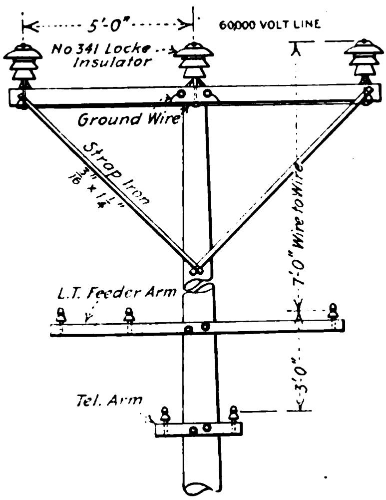


FIG. 22—WASHINGTON WATER POWER CO POLE TOP CONSTRUCTION FOR WILBUR HARTLINE TRANSMISSION LINE

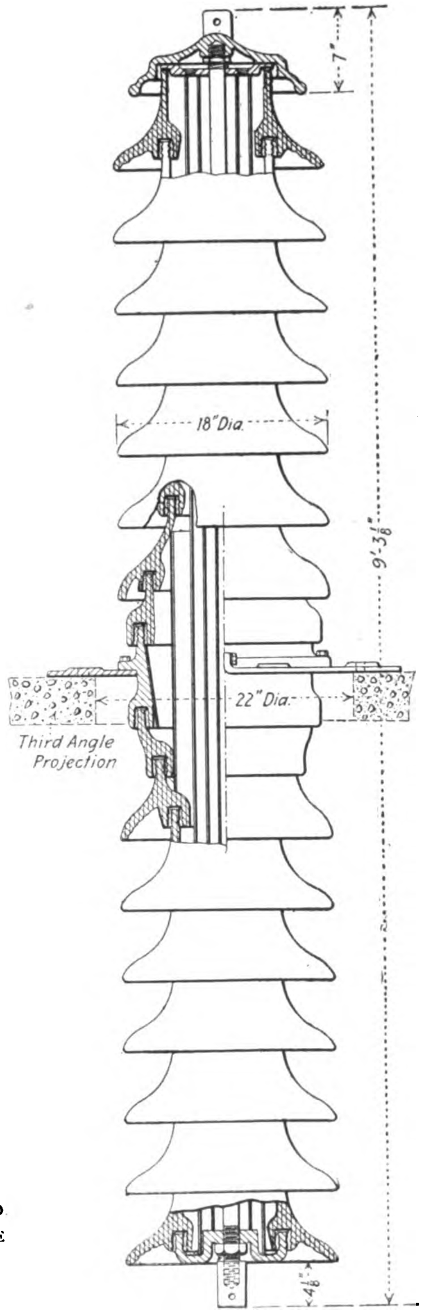


FIG. 23—MEXICAN LIGHT AND POWER CO. 85,000-VOLT ROOF BUSHING

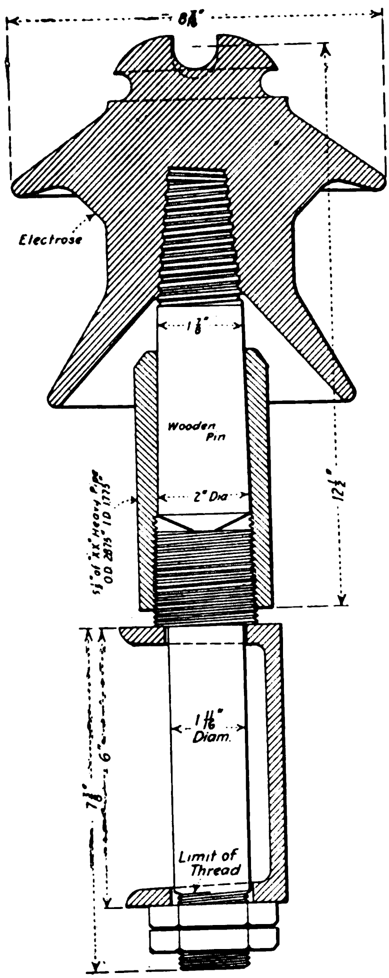


FIG. 24—NIAGARA FALLS POWER CO INSULATOR AND PIN

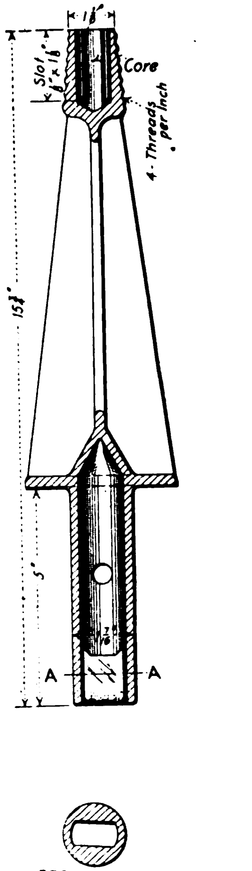


FIG. 25—PUGET SOUND TRACTION, LIGHT & POWER CO. INSULATOR PIN FOR CROSSARM, 60,000-VOLT POLE LINE, HEAVY CONSTRUCTION. SEE FIG. 26

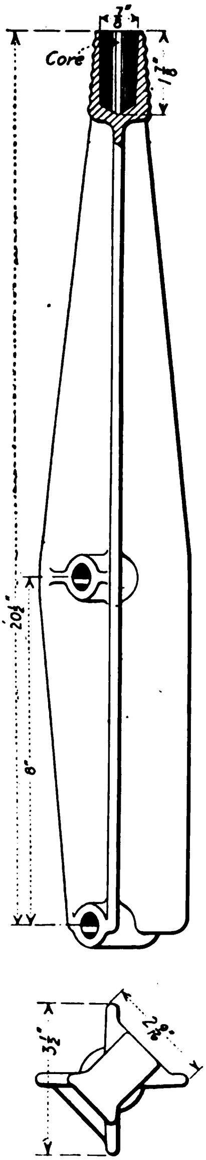


Fig. 26—Puget Sound Traction, Light and Power Co. Insulator Pin for Pole Top, 60,000-Volt Pole Line, Heavy Construction. See Fig. 25

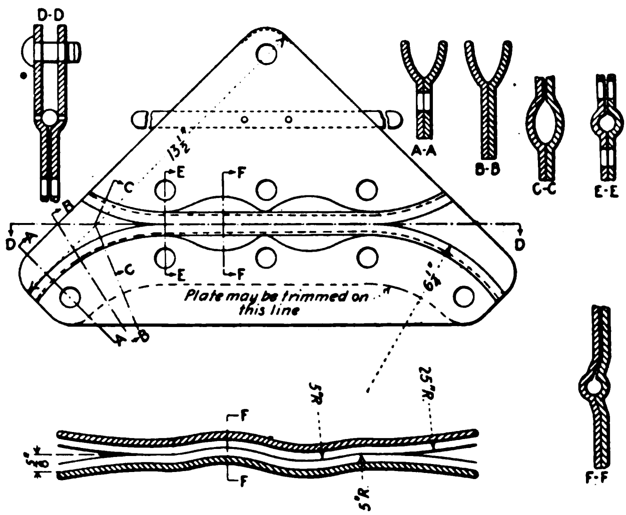


Fig. 27—Mississippi River Power Co. Conductor Cable Clamp

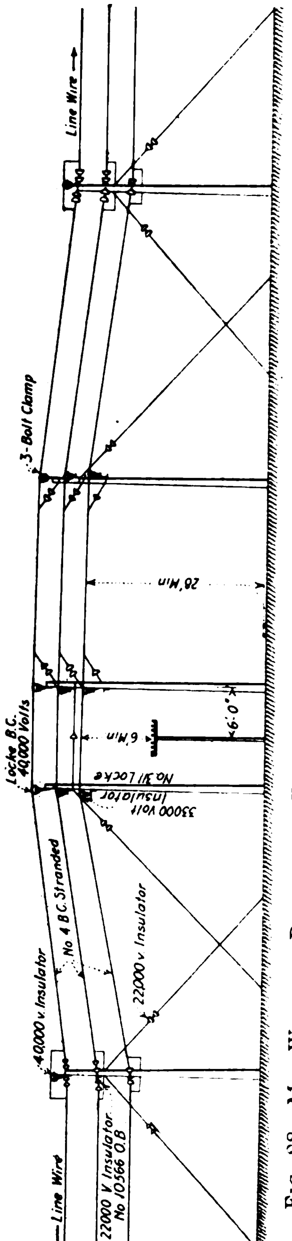


FIG. 28—MT. WHITNEY POWER AND ELECTRIC CO. STANDARD RAILWAY CROSSING NO. 3 FOR 6,600- AND 33,000-VOLT LINE.

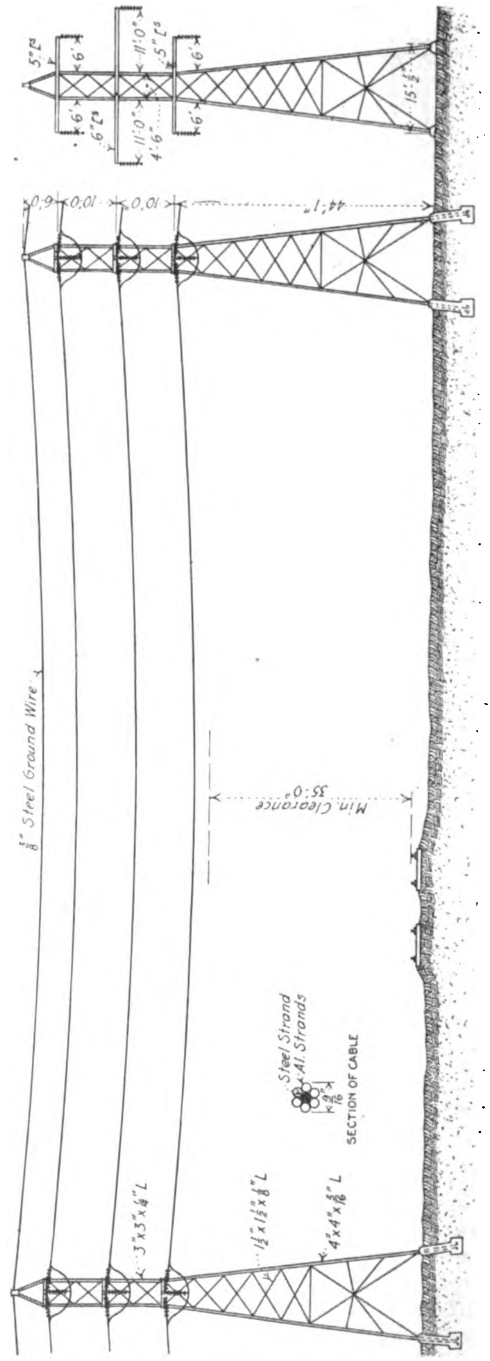


FIG. 29—SOUTHERN-SIERRAS POWER CO. PROPOSED CONSTRUCTION AT RAILWAY CROSSINGS

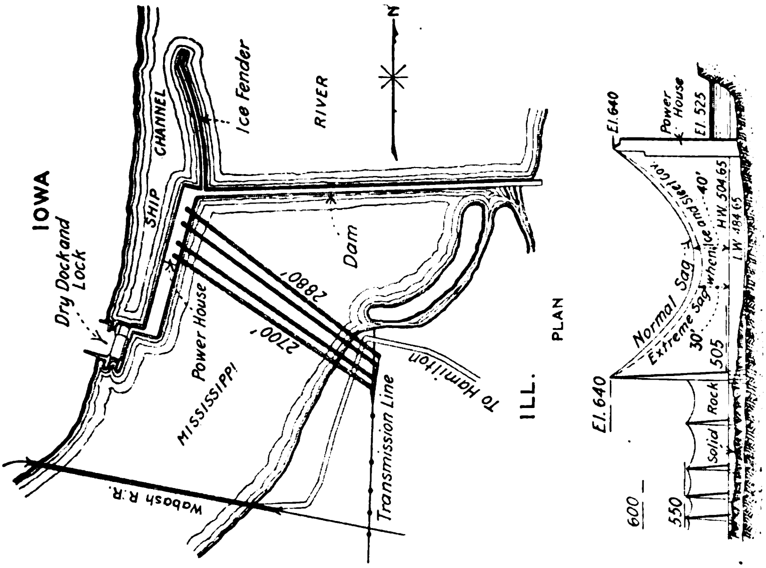


FIG. 31—MISSISSIPPI RIVER POWER CO. TRANSMISSION LINE CROSSING MISSISSIPPI RIVER AT KEOKUK, IOWA

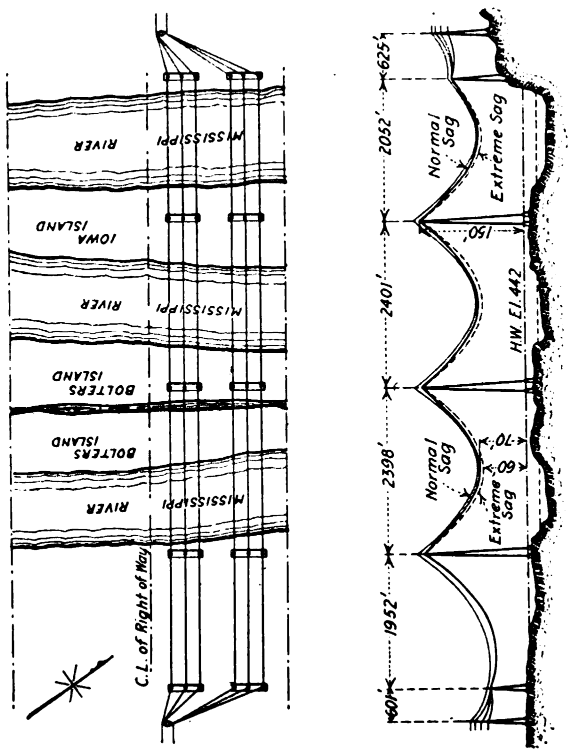


FIG. 30—MISSISSIPPI RIVER POWER CO. TRANSMISSION LINE CROSSING MISSISSIPPI RIVER AT IOWA ISLAND

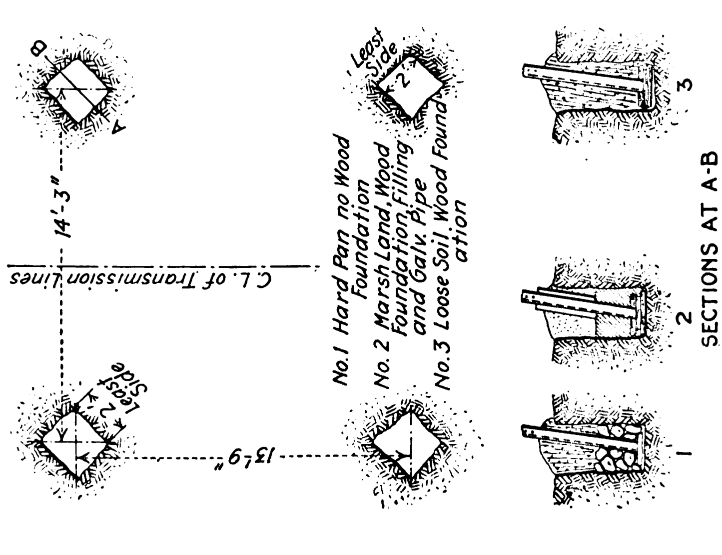


FIG. 32—MEXICAN LIGHT AND POWER CO., LTD. PLAN AND SECTIONS OF TOWER FOUNDATIONS]

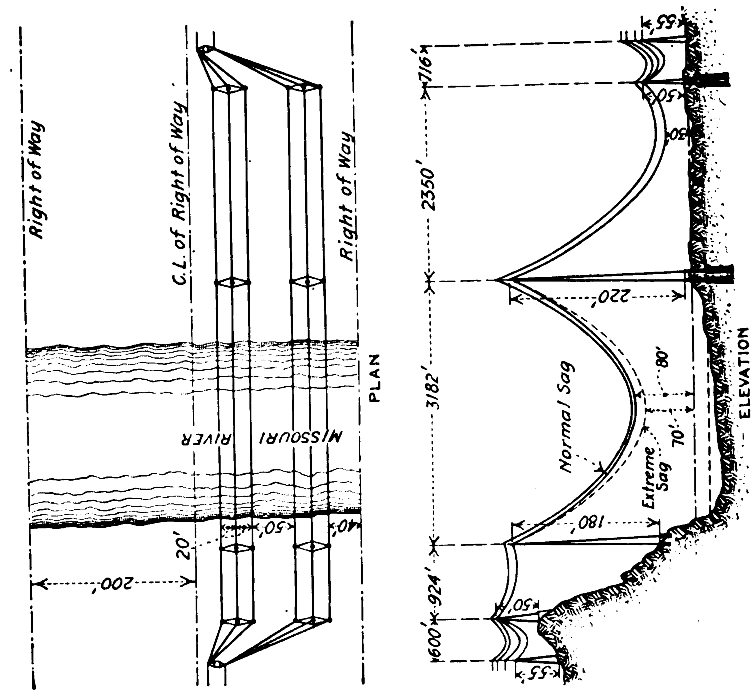


FIG. 33—MISSISSIPPI RIVER POWER CO. TRANSMISSION LINE CROSSING AT MISSOURI RIVER.

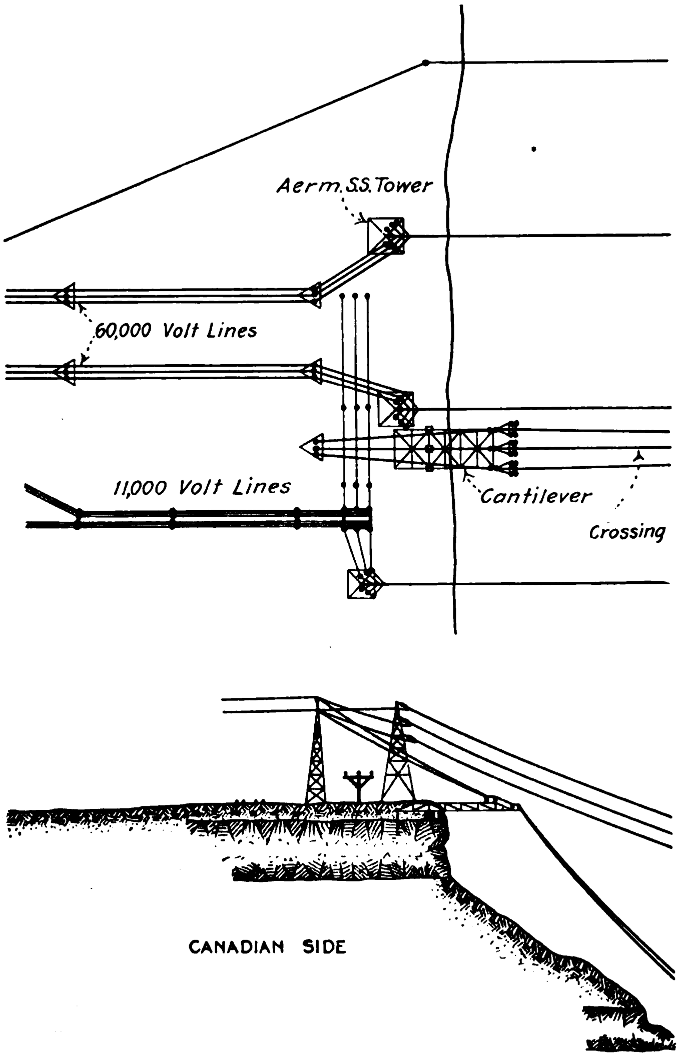


FIG. 34—NIAGARA, LOCKPORT AND ONTARIO POWER CO. PROFILE OF REVISED CROSSING OVER NIAGARA GORGE

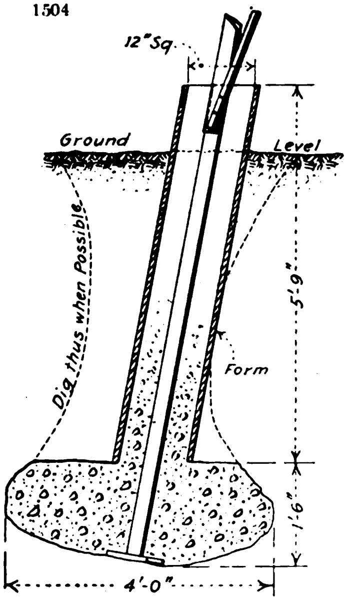


FIG. 35—GREAT WESTERN POWER CO. TOWER FOOTINGS FOR STANDARD TOWERS

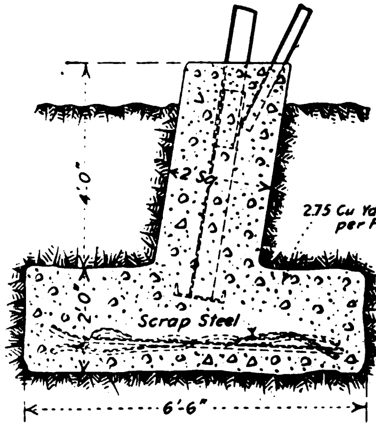


FIG. 36—GREAT WESTERN POWER CO. STUB FOOTINGS FOR 37 DEG. ANGLE TOWER ON COMPRESSION SIDE OF ANGLES

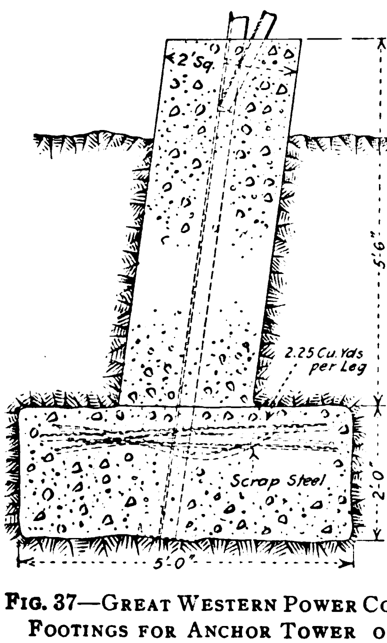


FIG. 37—GREAT WESTERN POWER CO. FOOTINGS FOR ANCHOR TOWER ON TENSION SIDE OF ANGLES.

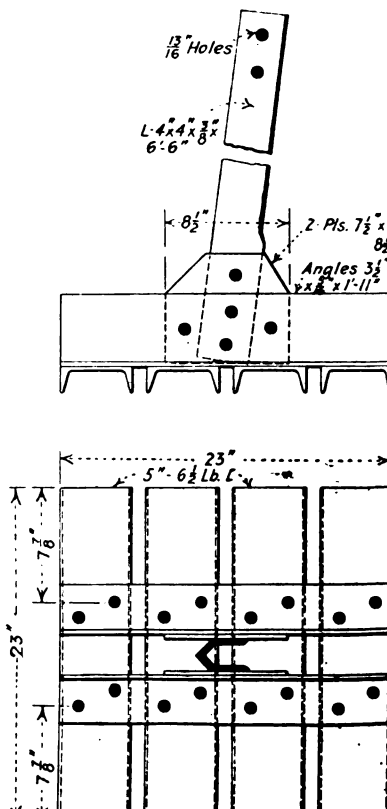


FIG. 38—WASHINGTON WATER POWER CO. GRAVEL ANCHOR FOR STEEL TOWERS

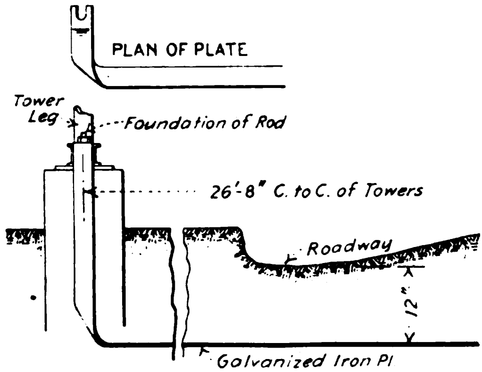


FIG 39—NIAGARA, LOCKPORT AND ONTARIO POWER CO. GROUND FOR TRANSMISSION LINE TOWERS

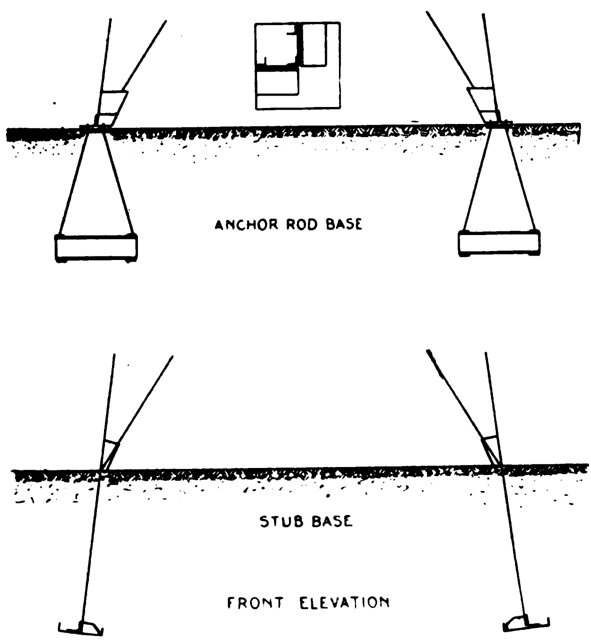


FIG. 40—GREAT WESTERN POWER CO. BASES FOR 37-DEG. ANGLE TOWER

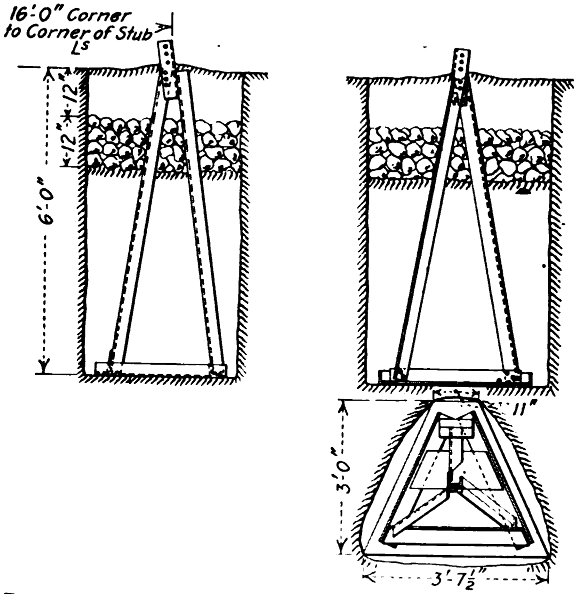
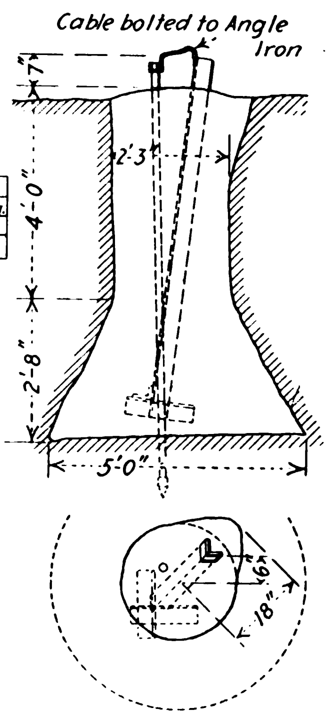


FIG. 41—PENNSYLVANIA WATER AND POWER CO. FOUNDATION FOR 40-FT. LIGHT SECTION TOWERS



	BASE
40' Tower	16'-0" Sq.
50' "	18'-9" "
60' "	21'-6" "

FIG. 42—PENNSYLVANIA WATER AND POWER CO. CONCRETE FOUNDATION FOR HEAVY TOWERS

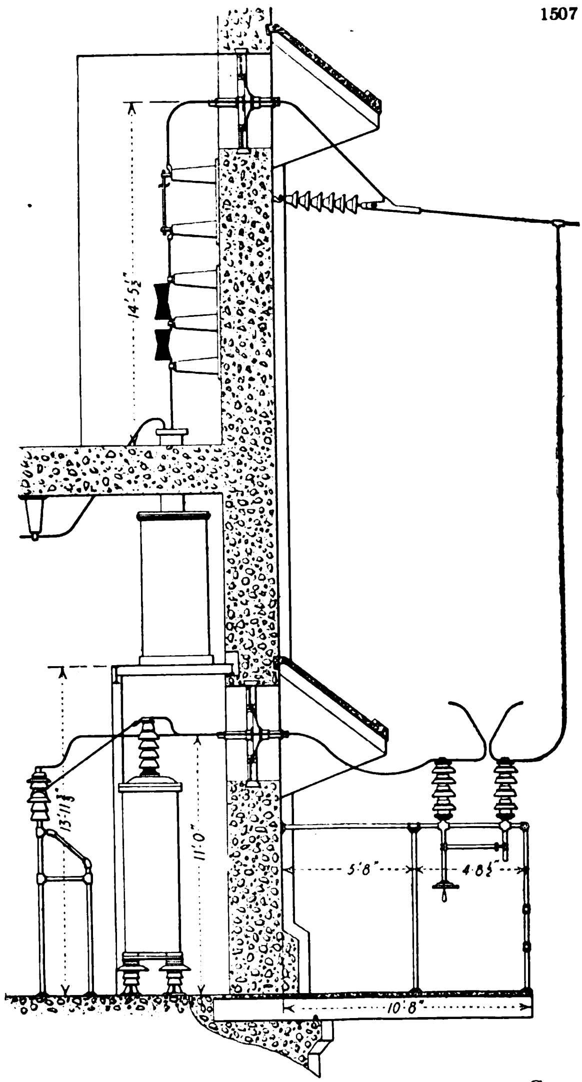


FIG. 43—PENNSYLVANIA WATER AND POWER CO. CROSS-SECTION THROUGH TRANSFORMER HOUSE, SHOWING OUTGOING LINE

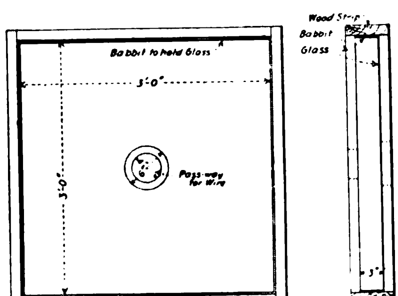


FIG. 44—WESTERN STATES GAS AND ELECTRIC CO. STANDARD EXIT FOR TRANSMISSION WIRES AT SUBSTATIONS

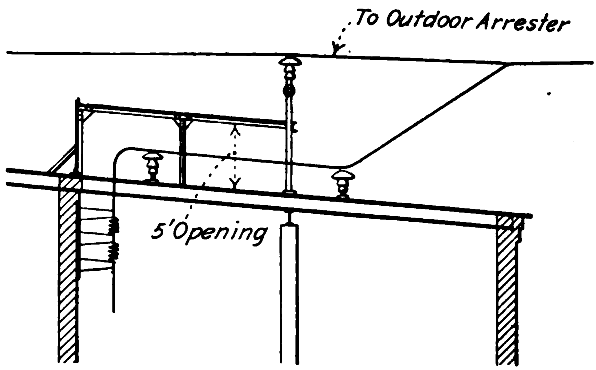


FIG. 45—MEXICAN LIGHT AND POWER CO. PROPOSED ROOF ENTRANCE FOR HIGH-TENSION LINES AT NONOALCO SUBSTATION

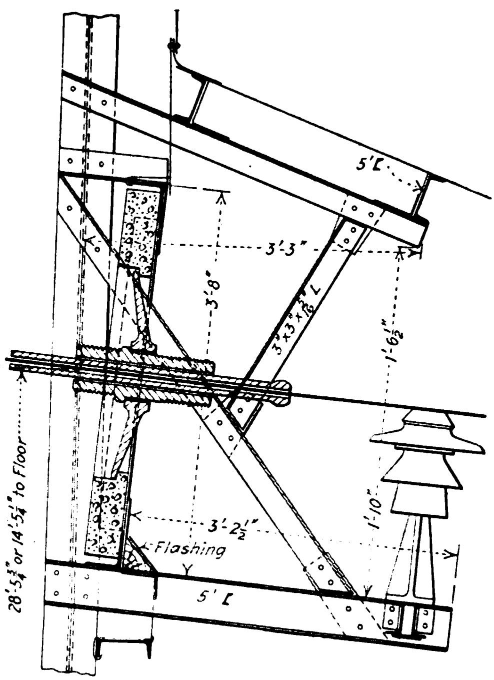


FIG. 46—WASHINGTON WATER POWER CO. 60,000-VOLT LINE ENTRANCE

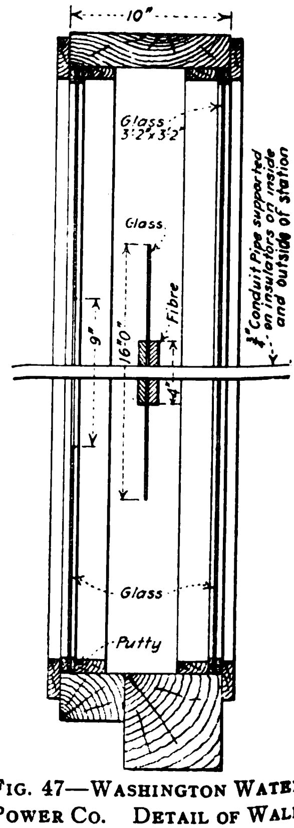


FIG. 47—WASHINGTON WATER POWER CO. DETAIL OF WALL ENTRANCE FOR HIGH-TENSION LINE, ODESSA SUBSTATION

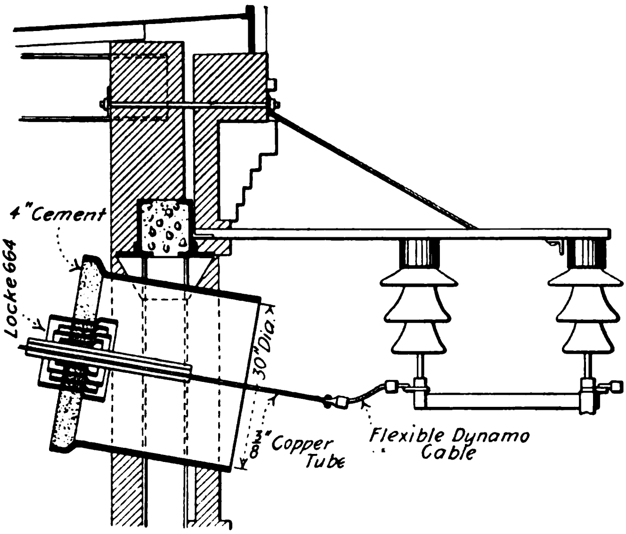


FIG. 48—NIAGARA, LOCKPORT AND ONTARIO POWER CO. DETAIL OF HIGH-TENSION OUTLET THROUGH WALL

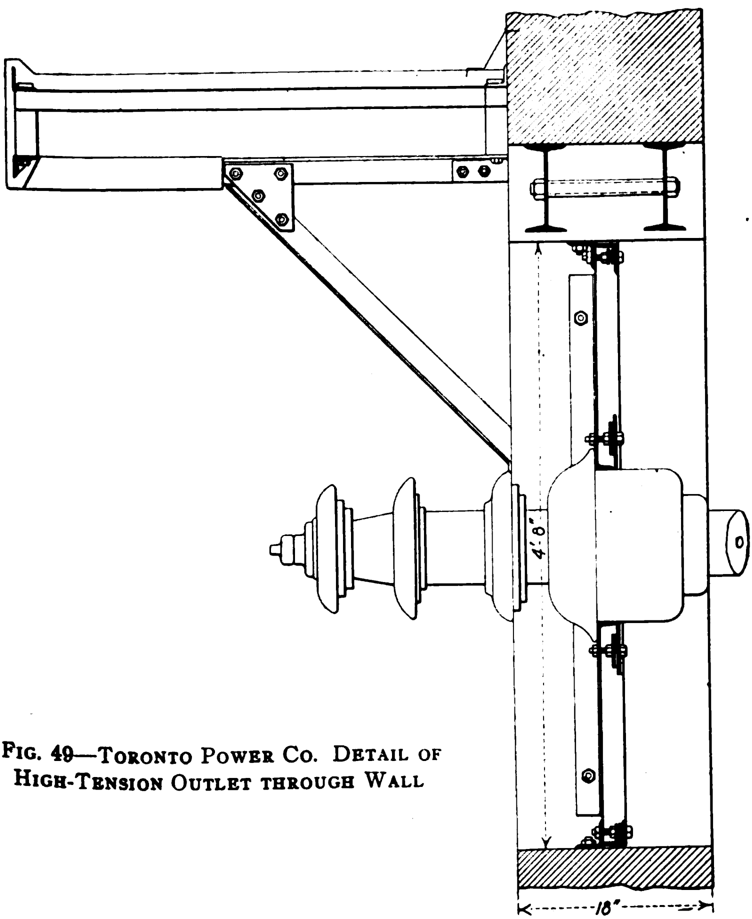


FIG. 49—TORONTO POWER CO. DETAIL OF HIGH-TENSION OUTLET THROUGH WALL

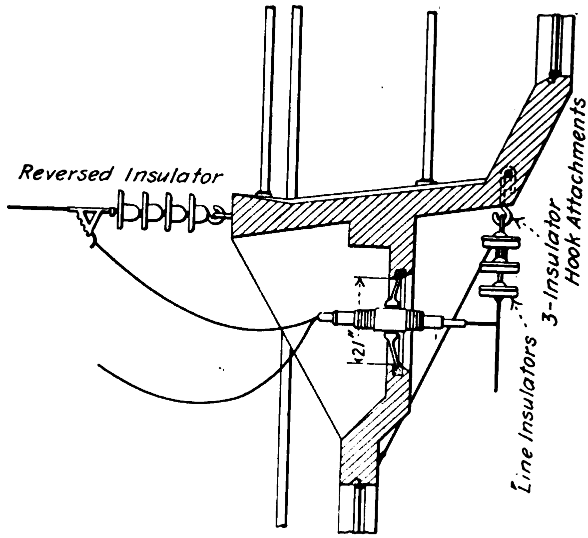


FIG. 50—PORTLAND RAILWAY, LIGHT AND POWER CO. ARRANGEMENT OF OUTGOING LINE BUSHING

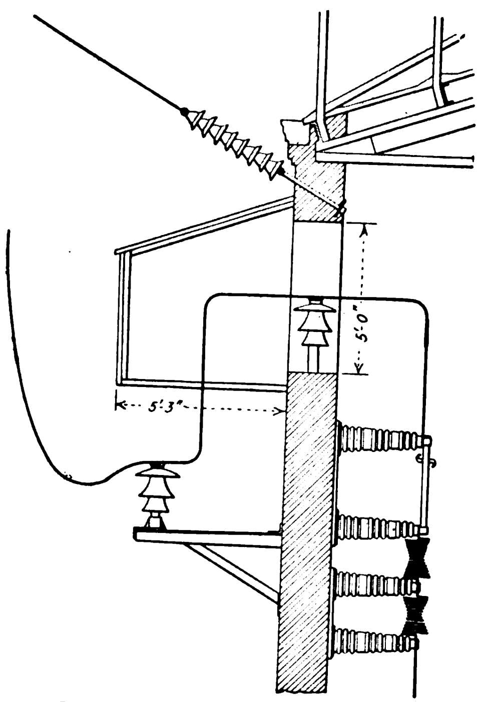
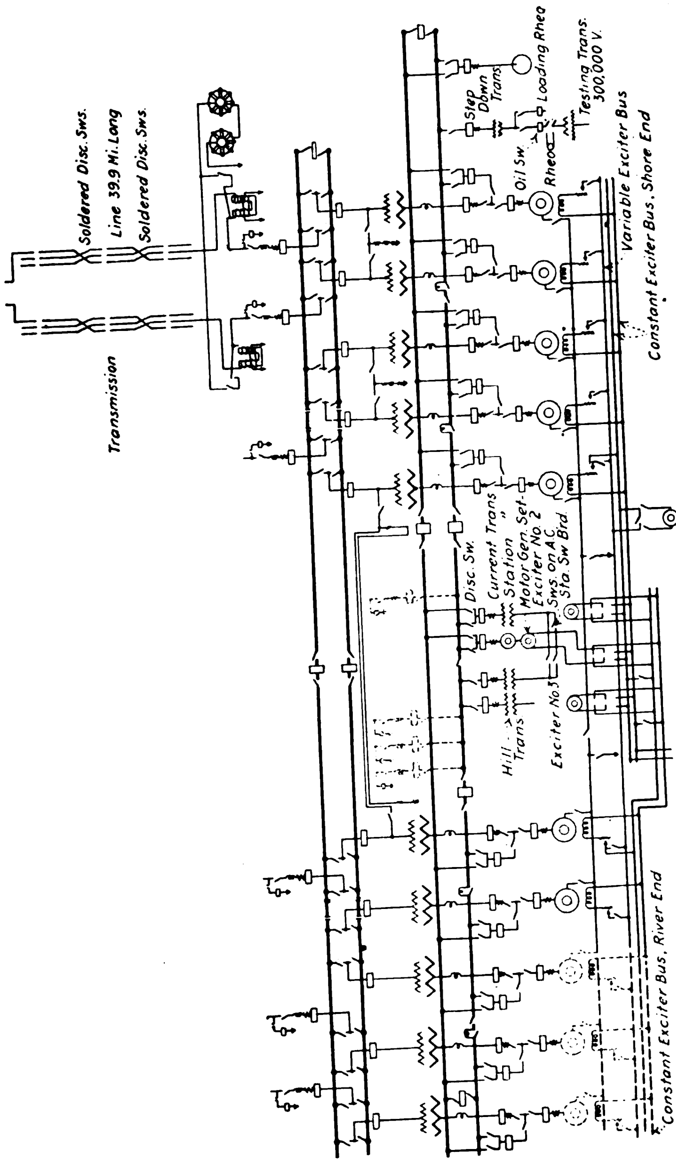


FIG. 51—MEXICAN LIGHT AND POWER CO., LTD. ARRANGEMENT OF OUTLET FOR LINE FOR 85,000 VOLTS AT NECAXA POWER HOUSE NO. 1



GENERATING STATION. HOLTWOOD, PENN

FIG. 52—PENNSYLVANIA WATER AND POWER CO. DIAGRAM OF GENERATING AND TRANSMISSION SYSTEM

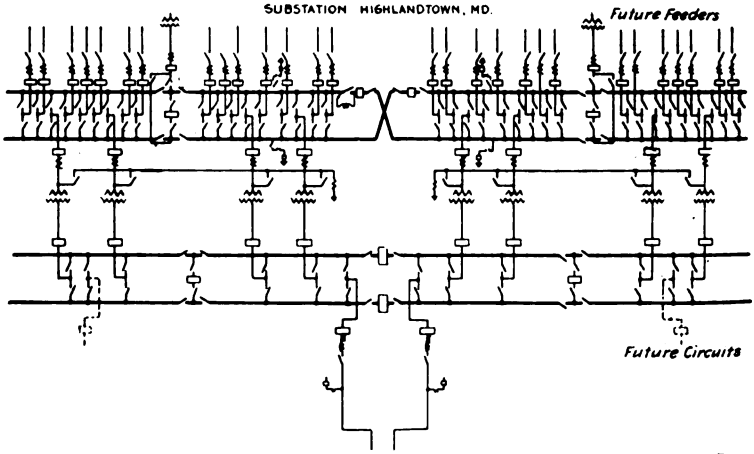


FIG. 53—PENNSYLVANIA WATER AND POWER CO. DIAGRAM OF SUBSTATION CIRCUITS

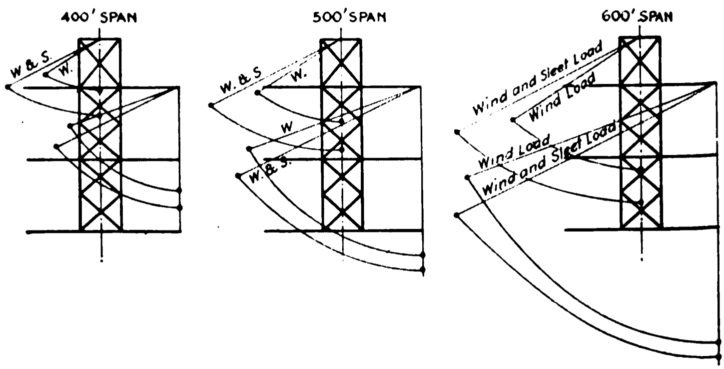


FIG. 54—PENNSYLVANIA WATER AND POWER CO. DEFLECTION OF CABLES FOR TRANSMISSION LINE NO. 1, BALTIMORE

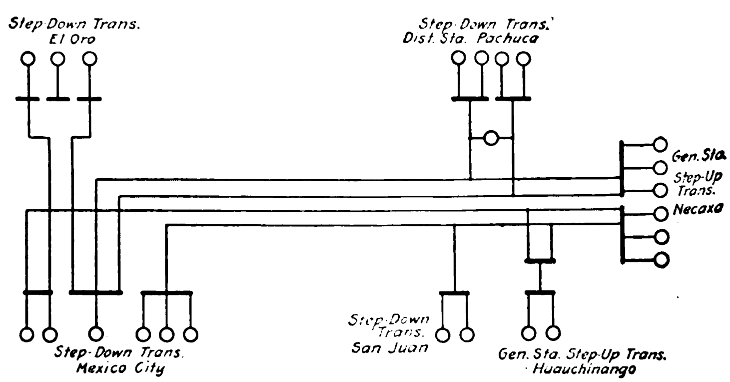


FIG. 55—MEXICAN LIGHT AND POWER CO., LTD. DIAGRAM OF HIGH-TENSION TRANSMISSION LINES

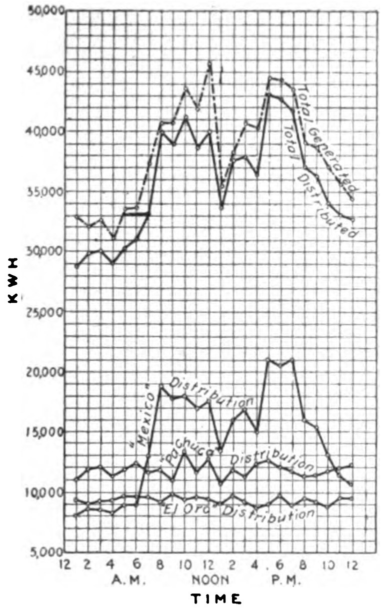


Fig. 56—Mexican Light and Power Co., Ltd. Typical Daily Load Curve

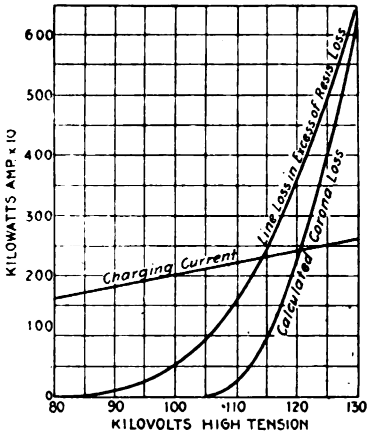


Fig. 57—Mississippi River Power Co. Line Charging Characteristics and Corona Losses

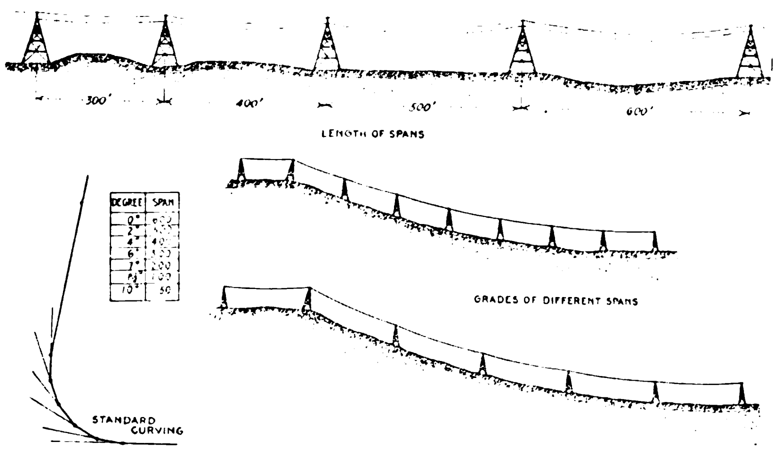


Fig. 58—Mexican Light and Power Co., Ltd., Vertical and Horizontal Angles.

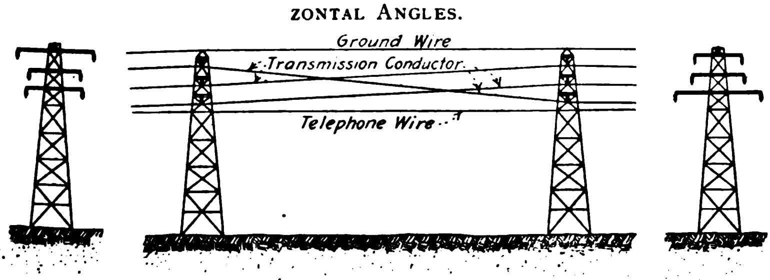


Fig. 59—Washington Water Power Co. Transposition

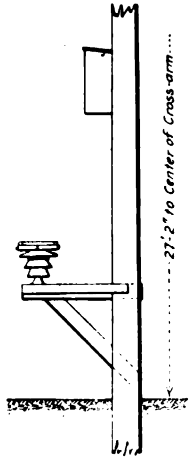


FIG. 60—WASHINGTON WATER POWER CO. DETAIL OF TELEPHONE INSULATING STAND FOR LINEMAN

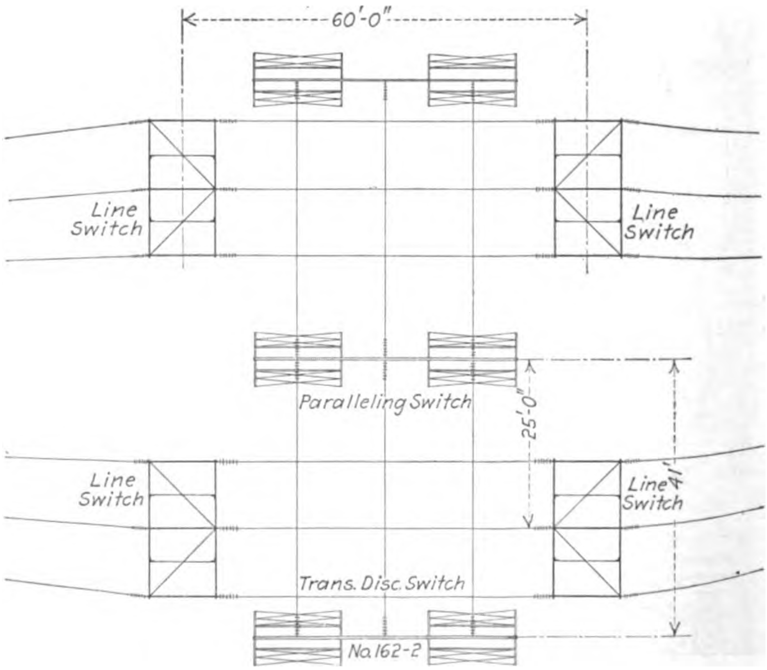


FIG. 61—SOUTHERN SIERRAS POWER CO. DIAGRAM OF SWITCHING STATION

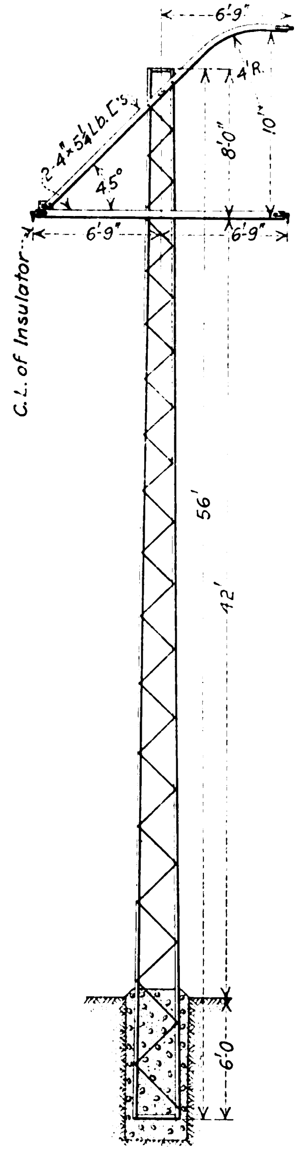


FIG. 62—SOUTHERN SIERRAS POWER CO.
DETAIL OF 56-FT. STEEL POLE

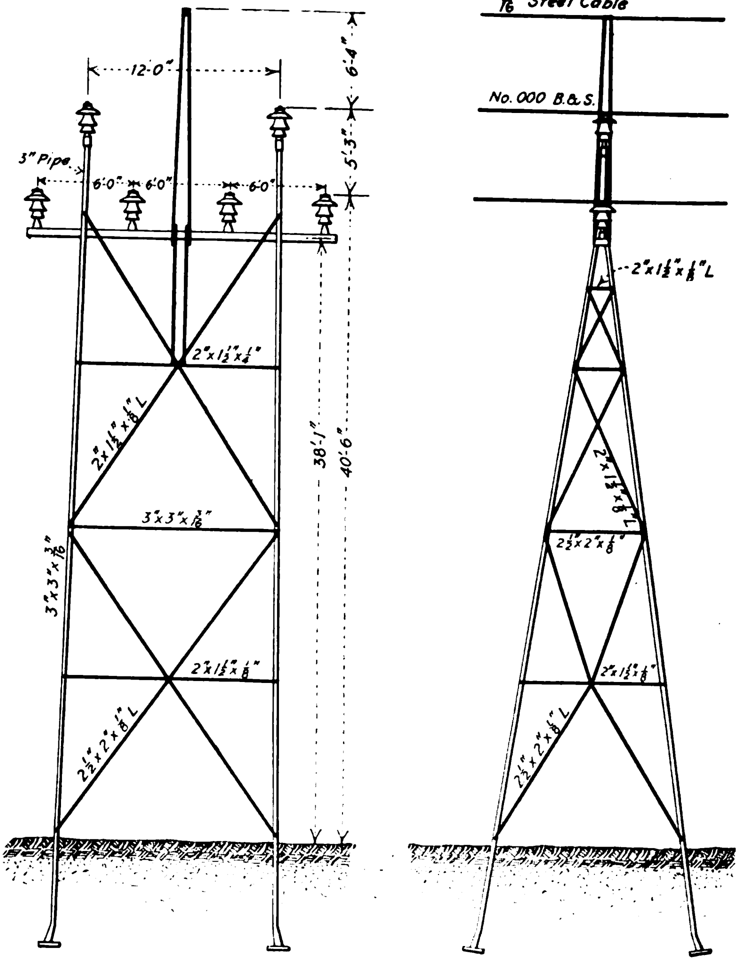


FIG. 63—MEXICAN LIGHT AND POWER CO., LTD. CONSTRUCTION OF STANDARD TOWERS

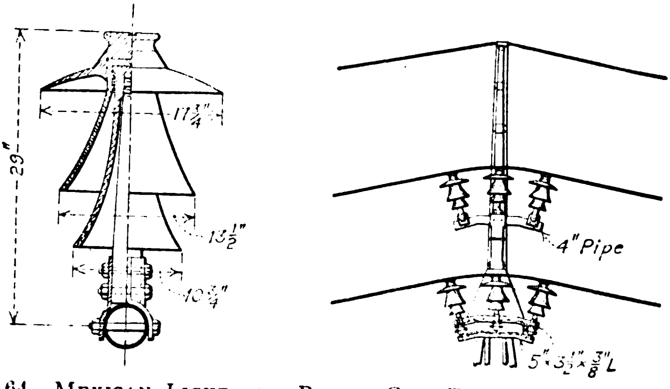
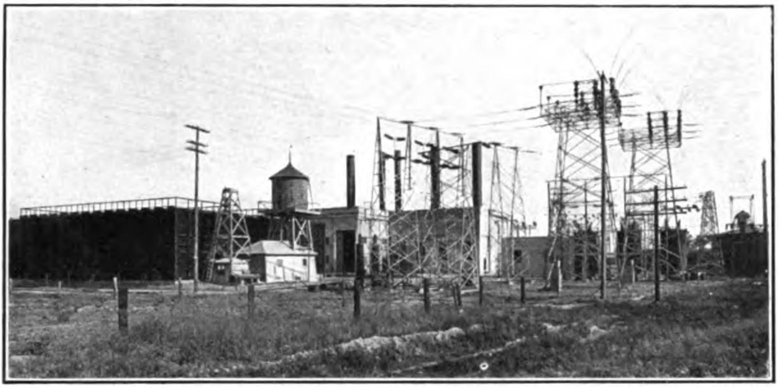
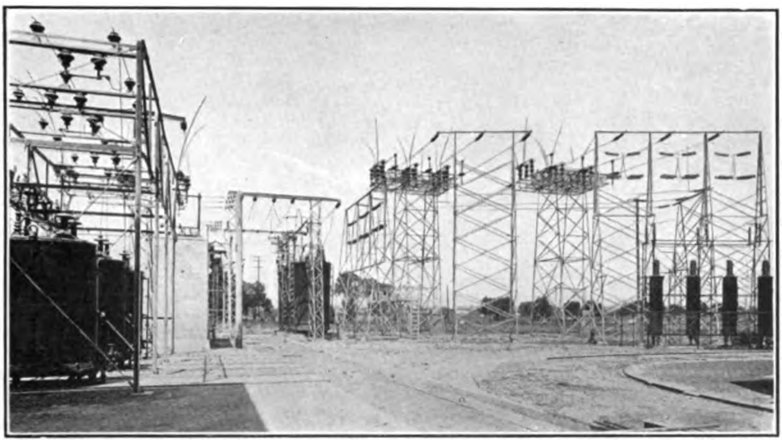


FIG. 64—MEXICAN LIGHT AND POWER CO. TOP OF SPECIAL TOWER AND SECTION OF 85,000-VOLT INSULATOR



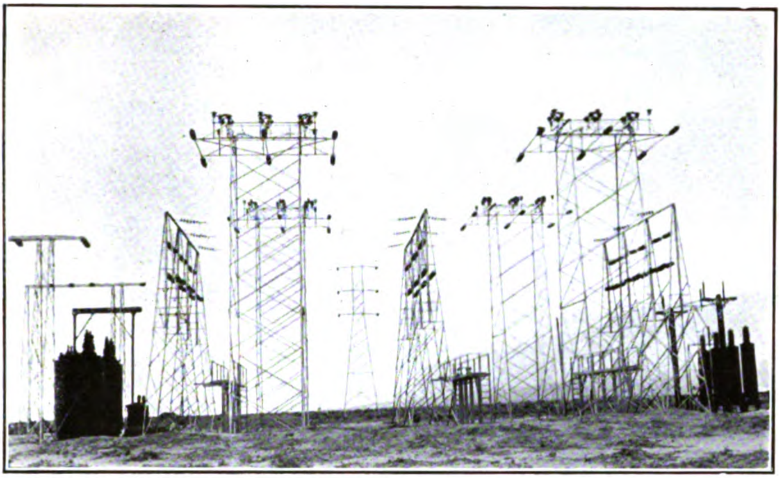
[THOMAS]

FIG. 66—SOUTHERN SIERRAS POWER CO. SAN BERNARDINO OUTDOOR TRANSFORMER STATION

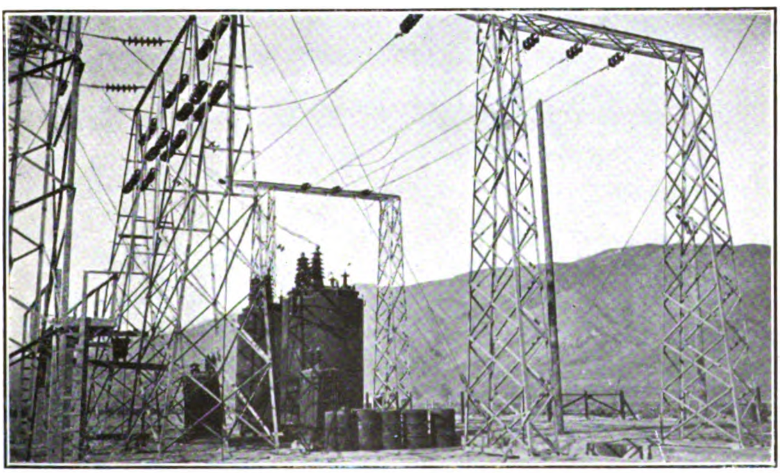


[THOMAS]

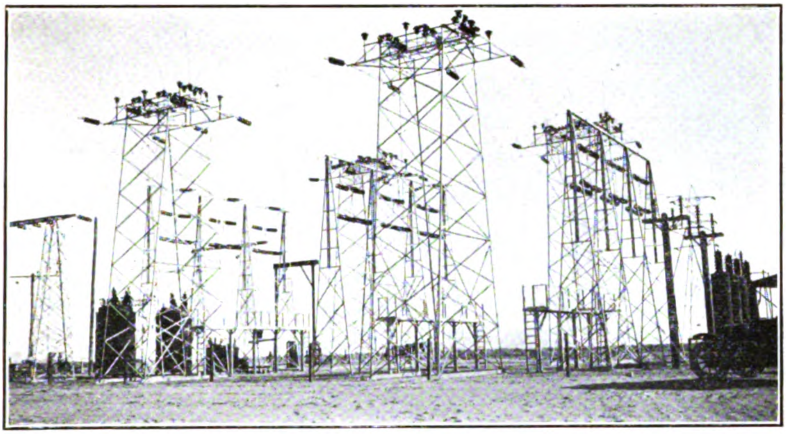
FIG. 67—SOUTHERN SIERRAS POWER CO OUTDOOR TRANSFORMER STATION AT THE SAN BERNARDINO GENERATING PLANT



[THOMAS]
FIG. 68—SOUTHERN SIERRAS POWER CO. LONE PINE SUBSTATION—60,000-VOLT NON-AUTOMATIC CIRCUIT BREAKERS

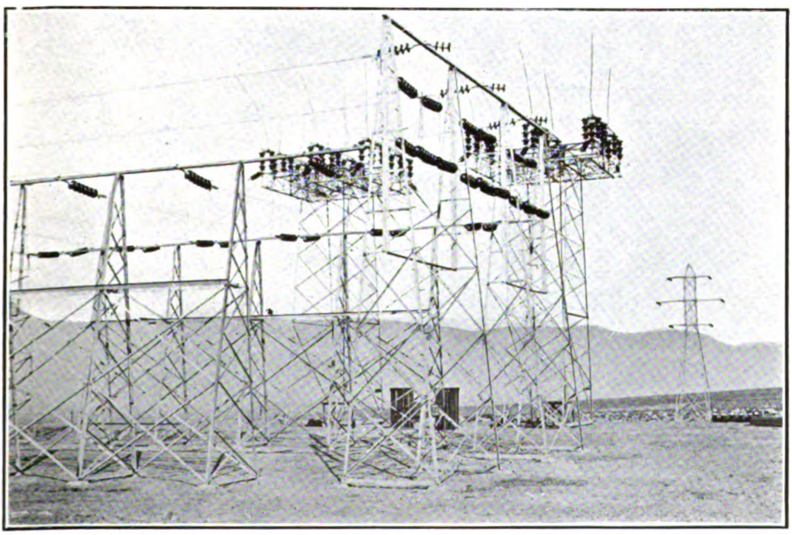


[THOMAS]
FIG. 69—SOUTHERN SIERRAS POWER CO. LONE PINE SUBSTATION



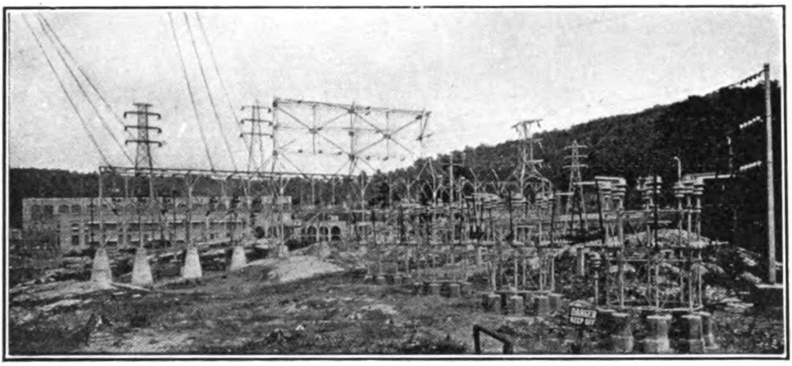
[THOMAS]

FIG 70—SOUTHERN SIERRAS POWER CO. VIEW OF SUBSTATION AT LONE PINE



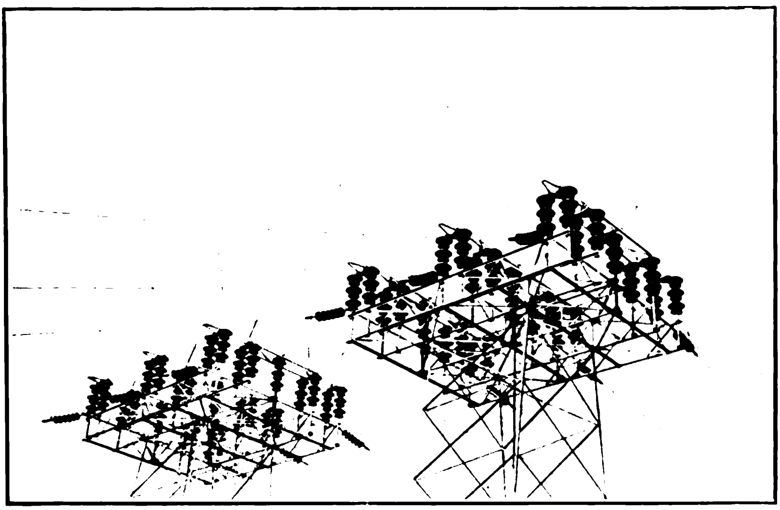
[THOMAS]

FIG. 71—SOUTHERN SIERRAS POWER CO. CONTROL STATION NEAR MOUTH OF BISHOP CREEK CANYON—COMMENCEMENT OF TRANSMISSION TO SAN BERNARDINO



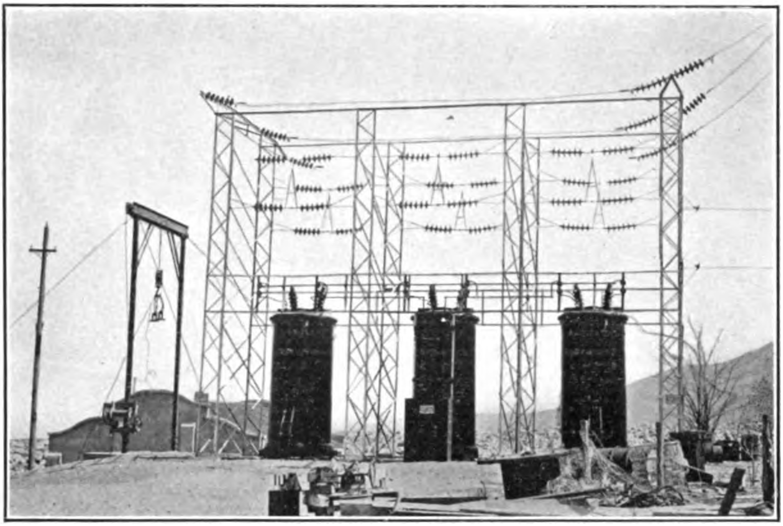
[THOMAS]

FIG. 72—PENNSYLVANIA WATER AND POWER CO. NICHOLSON'S LIGHTNING ARRESTERS



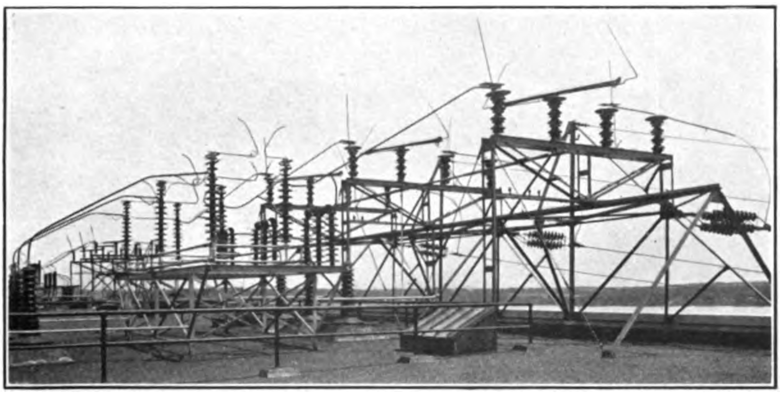
[THOMAS]

FIG. 73—SOUTHERN SIERRAS POWER CO. CONTROL STATION AT BISHOP, SHOWING DOUBLE BREAK, PNEUMATICALLY-OPERATED, SYNCHRONIZING CIRCUIT BREAKERS



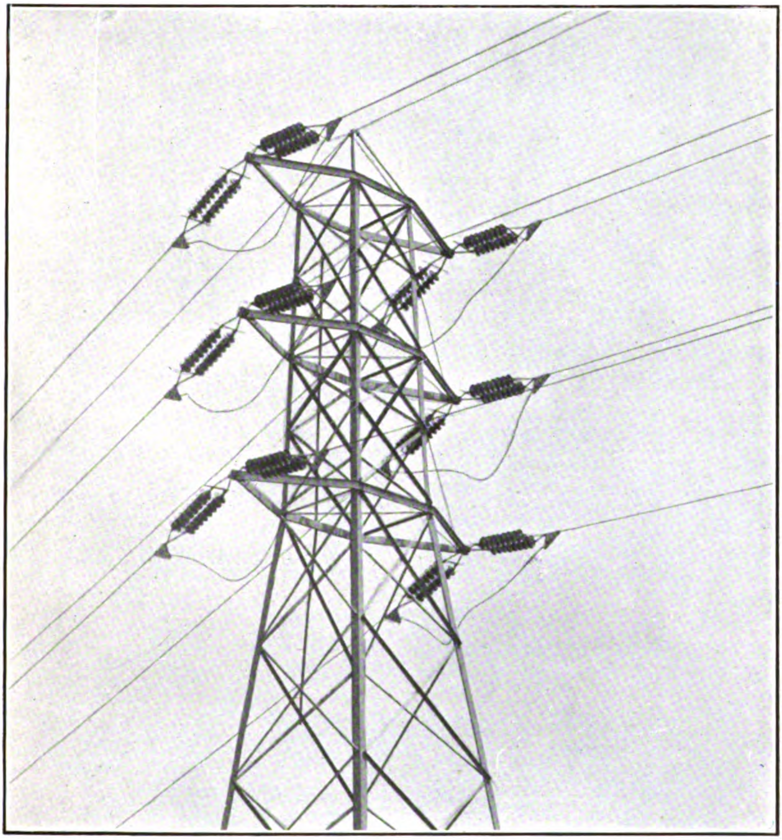
[THOMAS]

FIG. 74—SOUTHERN SIERRAS POWER CO. TRANSFORMER STATION, POWER PLANT NO. 6



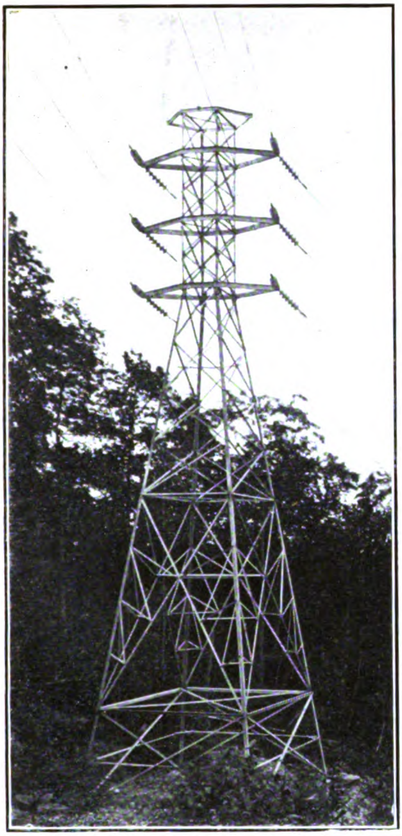
[THOMAS]

FIG. 75—MISSISSIPPI RIVER POWER CO. ROOF STRUCTURES FOR 110,000-VOLT LINE ENTRANCE



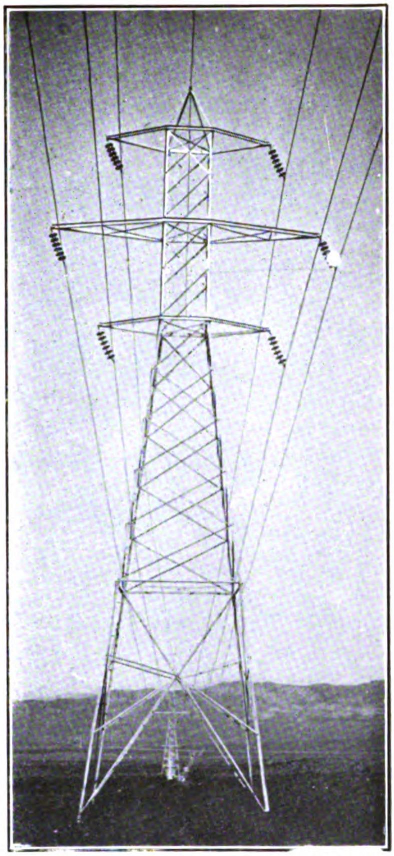
[THOMAS]

FIG. 76—MISSISSIPPI RIVER POWER CO. TURN IN LINE AT TOWER NO. 12



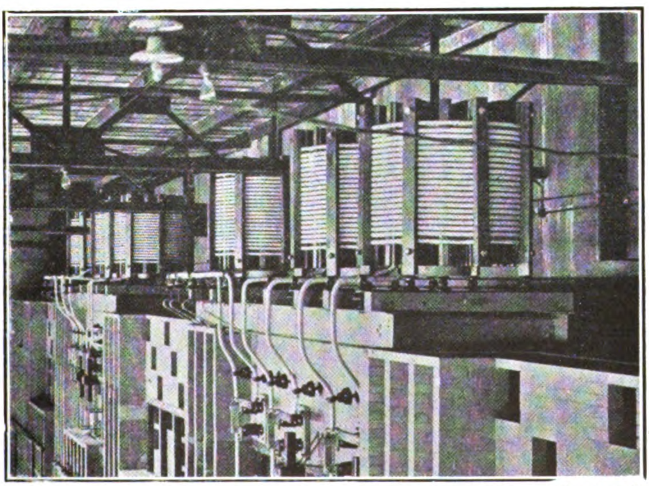
[THOMAS]

FIG. 77—PENNSYLVANIA WATER AND POWER CO STANDARD ANGLE TOWER



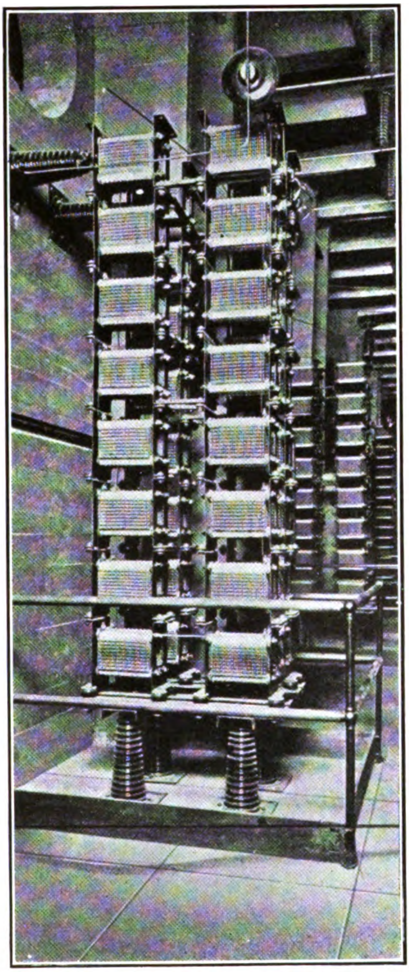
[THOMAS]

FIG. 78—SOUTHERN SIERRAS POWER CO. TRANSMISSION LINE UNDER WIND STRESS
(See deflection of insulators.)



[THOMAS]

FIG. 79—PENNSYLVANIA WATER AND POWER CO. PART OF INTERIOR OF SWITCH ROOM, GENERATOR STATION, SHOWING REACTANCES



[THOMAS]
FIG. 80—PENNSYLVANIA WATER AND POWER CO.
70,000-VOLT BUS ROOM, HOLTWOOD
RESISTANCES IN NEUTRAL GROUND CONNECTION

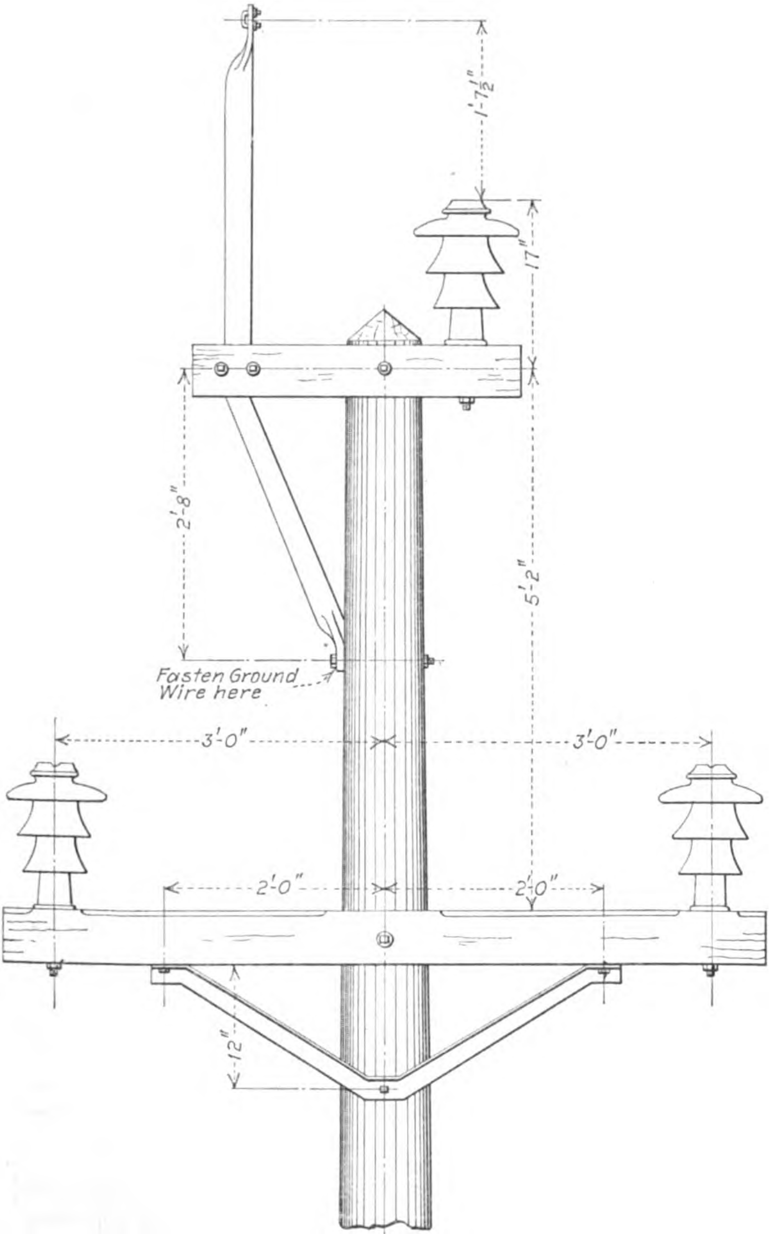


FIG. 65—"X." DETAIL OF POLE TOP—50,000-VOLT, SINGLE CIRCUIT TRANSMISSION LINE

APPENDIX

Following is the list of questions submitted to high-tension operating companies from which the answers to the foregoing data have been compiled.

A

THE LINE AS A STRUCTURE.

ONLY SYSTEMS OF 25,000 VOLTS OR HIGHER

1. Outline drawings of your standard high-tension lines. Side view of span and a view at the tower looking along the line.
2. Give height of pole or tower, dimensions and locations of crossarms and position of wires, distance between two circuits on same towers, foundations, show all overhead grounded wires, etc. Attach sketches hereto. Also give:
3. Total length of main line. Altitude. General air temperature range.
4. Size and material of conductor, core, if any, etc.
5. Length of standard span.
6. Sag is at temperature of deg. cent.
7. Manufacture and manufacturer's catalogue number of high-tension line insulator.
8. Material of insulator.
9. Standard clearance above ground at middle of span.
10. Minimum clearance above roadways. Over railways.
11. Details of pin construction.
12. Form of strain insulators. (Sketch preferred, with catalogue number and make of insulator.)
13. How many units in series?
14. Dry test given standard line insulator.
15. Dry test given strain insulator.
16. Wet test given line insulator.
17. Wet test given strain insulator.
18. How is the "loop" in the conductor around the strain insulators at an anchor tower made?
19. Describe fully any exceptionally long spans, and attach description hereto.
20. Describe any special features of line construction having particular interest.
21. Describe method of turning angle, horizontal or vertical, or main line.
22. Describe and show sketch of outlets from buildings for high-tension wires.
23. How are steel towers grounded?
24. Where systems at different voltages are connected together on the high-tension side, are auto transformers, or separate coil transformers, used?
25. What sorts of deterioration do you observe in the conductor, insulators or towers after long service?

B

CALCULATION OF LINE

CONDITIONS ON WHICH THE ORIGINAL DESIGN OF THE LINE WAS BASED

1. Size of conductors and elastic limit and modulus of elasticity assumed in the design .
2. Elastic limit and modulus by actual test.
3. Same for overhead grounded wires if used. Design value . Test value .
4. Breaking strength assumed in the design . Breaking strength by test .
5. Maximum strength pin, assumed in the design . As determined by test .
6. What maximum stress conditions were specified in the design for poles or towers, to determine their strength, e.g., was it made a condition that the line should stand, if all conductors were cut on one side of tower?
7. Maximum wind stress assumed for bare wire, pounds per square foot of projected area.
8. Accompanying air temperature assumed for question 7.
9. Maximum and minimum air temperatures assumed for determining limits of sag.
10. Maximum thickness ice assumed on conductor.
11 Accompanying air temperature assumed for question 10.
12. Accompanying wind pressure assumed for question 10, pounds per square foot of projected area.
13. Are special "strain" or "dead-end" towers used on tangents?
14. If so, where, and how often?
15. What stress conditions are these special towers designed to stand?
16. Have you any towers made flexible in the direction of the line?
17. If so, where are they placed, and how often have you dead-end towers?
18. What stresses are the flexible towers designed to stand, longitudinal and transverse?
19. If the outline of such flexible towers is not given under "Line Structure," please give sketch here.
20. Where suspension type insulators are used, what maximum angular deflection from the vertical under transverse wind strains was assumed in the design?
21. What was actually found (a) Steady wind conditions?
    (b) Swings?
22. What factors of safety were used in the design?
    a. Conductor, compare elastic limit with load .
    b. Tower structure .
    c. Overturning foundations .
    d. Overhead grounded wires .
23. Is the overhead grounded wire relied upon as part of the mechanical supporting structure in the direction of the line?

C

OPERATION

1. What is the standard method of cutting off high-tension lines, both for light and loaded lines?
2. How do you cut off a main line short circuit that holds on?
3. Do you use automatic overload circuit breakers? If so, where?
4. Are they instantaneous, inverse time limit or definite time limit?
5. What settings do you use on overload breakers and on time limit relays?
6. Do you use several relays with different time limits on different parts of a circuit and if so do the short time relays protect the others?
7. Do you use reverse energy relays? If so, what type?
8. When do they operate selectively? When non-selectively?
9. Can you clear a heavy main line short circuit without a synchronous load dropping out of step? If so, how, and under what conditions?
10. Do you operate any lines parallel at both ends? In this case can you cut out trouble on one line automatically without losing the load?
11. How do you locate line troubles?
12. Do you operate all lines from one busbar?
13. If so, is it a high-tension or low-tension busbar?
14. In case of several stations, are all connected directly to the same network?
15. How many power houses are connected to one system?
16. How many of these are water power?
17. How many are steam?
18. What are the capacities of each?
19. What is the maximum total load in system?
20. How do you regulate distribution of power between power stations?
21. How regulate voltage?
22. How do you secure constant voltage at intermediate points on a long line?
23. Where several power houses are connected to the same system, what happens when a short circuit occurs near one power house, that is how does it affect the rest of the system?
24. Is the high-tension netural gounded? If so, at how many points?
25. If so, is it through resistance?
26. Answer for each point of grounding.
27. If so, how much resistance?
28. How made up?
29. Have you ever operated, for even a brief period of time, with the line wire grounded?
30. If so, how long?
31. What was the effect on the rest of the system?
32. Have you a circuit breaker relay in connection with a grounded neutral to cut out automatically a single grounded line wire? If so, how arranged?
33. What is the total normal charging current of the system?
34. What is the power factor of the load at the generating station?

35. Do you use the method of operation which consists in dividing the plant into self-supporting groups and connecting the groups at some point to facilitate the carrying of peak loads and putting instantaneous overload breakers in these connections so that when trouble occurs in one section the others will be immediately cut off by these breakers and left to operate alone?
36. What are most common causes of interruption of service? If possible give the percentage of total interruptions caused by various kinds of trouble.
37. Have you any lead-covered cables operating at 20,000 volts or higher? If so, what sort? What success?
38. Are any such cables in series with overhead lines? If so, what protection is used.
39. What is the difference in voltage between the two ends of the line at full load? Specify the load and power factor at one end of the line and the length of the line.
40. How and where are the operations of the system controlled?
41. Do you have automatic voltage regulators on any of your generators?
42. If so, what kind? What results?
43. Have your oil switches ever failed to open a heavy load or short circuit?
44. If so, under what conditions? What type of switch?
45. Do you work on one line on a tower with another line alive?
46. As a matter of experience do your line insulators fail *on laboratory test* by flash-over, or by puncture?
47. As a matter of experience do your line insulators fail *in service* by flash-over, or by puncture?
48. Where suspension insulators puncture, which insulator in the string is the most likely to puncture?
49. Do the strain insulators fail more often than the vertical suspension strings?
50. Do you use synchronous apparatus to correct power factor? If so, how? With what success?
51. Do you use reactance coils for this purpose?
52. Have you had any trouble from mechanical oscillations or waves or swinging of your transmission conductor? If so, please explain.
53. At what frequency or frequencies do you operate?

NOTE. If the above questions are not suited to bring out the methods of operation or points of interest of your plant, please give such additional information as you may desire.

D

LIGHTNING AND LIGHTNING PROTECTION

1. What type and make of high-tension arresters do you use?
2. Where located in line? That is, whether indoors, outdoors, at exit from building, out on line, at what substations, etc.
3. Total number on lines
4. For what discharge voltage are they set, that is, at what margin over line voltage?
5. How often are they charged, if electrolytic arresters are used?

6. Is charging resistance used? Does this do away with high-frequency effect at time of charging?
7. How many lightning storms in average season?
8. How often do arresters discharge?
9. Do they discharge whenever one leg of the line is grounded?
10. How long will they stand a continuous discharge safely, as when there is a permanent ground on a line wire?
11. How many interruptions of service on main line per season due to lightning?
12. How many cases of high-tension station apparatus injured by lightning per season?
13. How many line insulators *punctured* by lightning per season?
14. How many line insulators *cracked* by arc over surface per season?
15. Are resistances used in ground connections of lightning arresters?
16. If so, how much?
17. Of what material and how made?

NOTE. If you have had any experience with overhead grounded guard wires on your transmission line, please summarize your evidence as to their effectiveness and give as a separate statement your views as to the desirability and effectiveness of such protection.

E

SPECIAL PROTECTION FEATURES

1. Do you use arc "suppressors?"
2. Do you use automatic grounding devices?
3. Do you use automatic line short-circuiting devices?
4. If you use any of the above, please give a brief outline of their principle of operation and your experience with them as fully as you may be willing to do so?
5. Do you use any other special forms of protective apparatus against short circuits, interruptions, or grounds, such, for example, as static cable protectors?
6. Do you use reactance coils in you circuits to prevent too heavy short-circuit currents?
7. If so, where are they located, in the system?
8. What maximum current do they permit on full voltage?
9. What could be the maximum short-circuit current of the system at the same point without these reactances coils.
10. Have you had any objectional features of such reactance coils develop?
11. Do you lower the generator field strength in case of trouble, either by hand or automatically?

F

TELEPHONE

1. How does your company telephone line run on the transmission poles or towers?
2. If not, how is it run and by what route with regard to the main line?

3. What size and material are the conductors?
4. How far spaced from transmission line, how are the telephone lines themselves spaced?
5. How transposed?
6. How is power line transposed?
7. What precautions are taken to protect users of the company phones?
8. Is the phone usable at all times during operation?
9. If not, when is it not usable?
10. What is the effect of the telephone line of various sorts of trouble on the transmission line?

G

PRESERVATION OF WOOD

1. Do you use any treated wood?
2. If poles, how do you treat them?
3. If crossarms, how do you treat them?
4. If pins, how do you treat them?
5. How have they lasted? What length of time and under what general conditions?
6. How much does it cost to treat?
7. What disadvantages has treating?
8. For what conditions do you advocate wood, the use of wooden poles or crossarms?
9. Have you any special means of protecting pole butts from decay or fire?

H

MISCELLANEOUS

1. Have you out door substations?
2. Have you outdoor transformers?
3. Have you outdoor switches?
4. If either, please state essential features briefly and whether you are pleased with them.
5. Do you use "breathers" to keep moisture from tanks of outdoor type ofapparatus? What sort and what success?
6. Does moisture actually penetrate your weatherproof tanks?
7. How do the high-tension terminals act in wet weather?
8. How do you protect tanks from the heat of the sun?
9. Have you tested oil from outdoor apparatus that has been over a year in service? If so, what result?
10. Do you follow the overhead crossings specifications prepared for the national standard by the Joint Committee on Overhead Line Construction of the N. E. L. A.?
11. Do you use any bimetallic or copper-clad cables?
12. If so, are they satisfactory? How used?
13. Any observations on corona?

Presented at the 31st Annual Convention of the American Institute of Electrical Engineers, Detroit, Mich., June 25, 1914, under the auspices of the Engineering Data Committee.

SPECIFICATION FOR INSULATOR TESTING

COVERING INSPECTION AND TESTS OF HIGH-TENSION LINE INSULATORS OF PORCELAIN, FOR OVER 25,000 VOLTS

The following specification was prepared by the High-Tension Transmission Committee of 1912-13, and was revised by the Engineering Data Committee of 1913-14. The committees preparing and revising this specification were as follows:

HIGH-TENSION TRANSMISSION COMMITTEE—1912-13

PERCY H. THOMAS, *chairman*

H. E. BUSSEY	HAROLD PENDER
MAX COLLBOHM	NORMAN ROWE
G. FACCIOLI	C. S. RUFFNER
P. T. HANSCOM	DAVID B. RUSHMORE
JOHN HARISBERGER	HARRIS J. RYAN
R. F. HAYWARD	P. W. SOTHMAN

ENGINEERING DATA SUB-COMMITTEE—1913-14

PERCY H. THOMAS, *chairman*

N. A. CARLE	C. S. MCDOWELL
F. F. FOWLE	HAROLD PENDER
H. M. HOBART	E. B. ROSA
L. E. IMLAY	W. S. RUGG
O. A. KENYON	C. E. SKINNER
A. S. MCALLISTER	C. W. STONE

SPECIFICATION

Introductory:

This specification covers certain methods of test and inspection which have been found well suited for testing high-tension line insulators for use under the ordinary conditions of power transmission work. It is expected to serve as a skeleton or model specification and may be supplemented by such additional provisions as may be appropriate for any particular case. Certain portions of the specification are added as a guide where designs are to be offered by several bidders for competitive tests. In such a case bidders will understand all the tests they must ultimately meet.

GENERAL SPECIFICATION COVERING ALL TYPES OF INSULATORS

1. (a) This specification is intended to cover the checking of the design and the testing and the inspection of the factory output, of..............................porcelain insulators, cat. No.................. of..................................Company; to be manufactured for the ....Company.

(b) The operating voltage is...........................and the frequency is............................

c. Definitions: By "insulator" is meant the complete insulator or group of insulating members including all the parts necessary to support the conductor from the crossarm or on the pin as the case may be.

By "unit" or "unit insulator" is meant a suspension insulator element complete, having a metal cap and pin.

By "shell" is meant a single porcelain piece without cement or cap or pin.

2. *Drawings:*

A dimensioned drawing shall be furnished showing the complete insulator and metal parts, or, if the insulators are built up or composed of a string of units, showing the details of a unit and all the clearances between units and hardware.

3. *Inspection:*

The maker will give to the purchaser or his representative such access to his works at all times during working hours as is reasonable and necessary to determine the suitability of material to be supplied, and shall furnish all necessary apparatus, labor, and other facilities for making the tests herein called for without cost to the purchaser. All good insulator units destroyed in the

tests here called for are to be paid for by the purchaser at the contract price.

All insulators are subject to final inspection, test and acceptance at maker's factory.

Neither the inspection nor waiving of inspection or the purchaser's acceptance will relieve the maker from obligation to furnish material in accordance with this specification.

4. *Design:*

All insulators shall be designed as far as may be practicable to fail by flash-over and not by puncture under excess voltage tests, especially under impact tests.

Insulators shall be of robust construction and design so as not to be easily injured in handling.

Explanatory Note:

The ultimate criterion of the merit of an insulator is its performance in service and the best available measure thereof is its behavior under definite tests. However, as no practicable tests actually reproduce service conditions, for example in the matter of high-frequency voltage or deposits of dust, criticism on theoretical grounds is valuable, and, other things being equal, preference should be given to the insulators most closely conforming to theoretically best designs.

NOTE. Careful attention in specifying flash-over voltages should be given to the fact that for varying altitudes the breakdown strength of air varies approximately though not exactly as the barometric pressure.

METAL PARTS

5. *Corrosion:*

All metal parts shall be of non-corrodible material or shall be galvanized or sherardized in accordance with the specifications for galvanizing prescribed by the joint committee of the National Electric Light Association in its Specification for Overhead Crossings of Power Lines Above Telephone and Other Low-Voltage Lines. Surfaces shall be free from roughness or projecting points; bearing surfaces shall be smooth enough not to injure cables.

6. *Factor of Safety:*

Metal parts shall have a factor of safety of at least three over the maximum stress that they receive in service, except that with pins for pin type insulators the factor may be reduced to two where a higher factor is impracticable. The maximum service strain is here agreed upon as———lb.

Porcelain

7. *Quality:*

All porcelain shall be dense and homogeneous as is best adapted to high-tension insulator requirements, free from injurious cracks, blisters and flaws or other defects that would render them unfit for use in insulators. The burning of all porcelain sections shall be done so as to insure even vitrification but shall not render the porcelain unduly brittle. The surface shall be smooth and uniform and the body of the porcelain shall be moisture-proof.

8. *Glazing:*

The glazing shall be of....................color and of a reasonably uniform shade, smooth, hard and continuous over all surfaces except those to be in contact with the cement. It shall be unaffected by weather, ozone, nitric acid, nitric oxides, alkali dust, or sudden changes in temperature over the atmosphere range.

9. *Absorption: Explanatory note.*

While imperviousness of the porcelain to moisture is of supreme importance, no satisfactory test of this quality is known.

Cement

10. *Assembling:*

All cemented joints between insulator parts shall be carefully made, using for this purpose the best grade of neat Portland cement, thoroughly mixed, and plentifully supplied with moisture during setting. The assembly shall be so done that no hollows or voids will be left between the cemented surfaces. All superfluous cement must be cleaned off of the insulator before crating.

Electrical Testing

Note. Sections 11 to 15 inclusive are particularly applicable to competitive tests and to tests the results of which are to be compared to similar tests made with other testing apparatus. In cases where merely a comparative study of different designs of the same make is to be made, all tests being carried out on the same testing apparatus, it is usually satisfactory to use the standard test apparatus of a first-class maker.

It should be definitely stated in the contract whether sections 11–15, inclusive, are to be adhered to or not.

11. *Wave Form:*

The wave form of the generator shall be a true sine curve within the limits specified for generators by the Standardization Rules

of the American Institute of Electrical Engineers and may be checked by the methods therein prescribed.

12. *Control of Voltage:*

The voltage shall be controlled in such a way as not to distort the wave form. One satisfactory method of control is the use of a regulator consisting of a shunt resistance connected directly across the low-voltage side of the transformer, and a series resistance in the supply. The shunt resistance must always by-pass at least five (5) times the exciting current of the transformer. The principal control is effected by the series resistance. This method is often spoken of as the potentiometer method.

13. *Measurement of Voltage:*

The method of measuring the voltage on the test circuit shall be that method recommended by the American Institute of Electrical Engineers, covering such cases.

14. *Kilowatt-Ampere·Capacity of Testing Apparatus:*

The kilovolt-ampere capacity of the testing apparatus, including any series resistance used, is important, for the leading current taken by the insulators tends to alter the voltage of the test apparatus. The maximum current taken from the test apparatus shall not be so great as to distort the voltage wave more than permitted for generator electromotive force waves by the A.I.E.E. Standardization Rules.

15. *Surrounding Conditions During Tests:*

In *design checking* tests of insulators having an operating voltage not exceeding 75,000 volts, no object other than leads and supports should approach nearer than 6 ft. (1.8 m.) to the insulator. For insulators having a higher operating voltage, the conditions for the " design test " of complete insulators should be made as nearly as practicable the same as the conditions of actual service as regards the grounding of one side of the insulator and the arrangement and distance of grounded objects in the neighborhood. A conductor of 6 ft. (1.8 m.) or more in length, extending equally on both sides of the clamp, should be used to represent the transmission wire.

NOTE—In these tests the walls of the room will ordinarily introduce a very serious departure from the conditions of outdoor service. Open-air tests where feasible are preferable from this point of view.

Routine tests, not being on complete insulators or insulator strings, do not require these precautions.

16. *Frequency:*

Tests should be made at the frequency at which the insulator is to be used. Where special agreement is made tests may be made at 60 cycles on insulators intended for use on higher and lower frequencies. No error of a serious magnitude will be expected within the range of 25 to 133 cycles.

17. *What Constitutes a Breakdown or a Flash-over:*

An insulator is said to "fail" or "break down" under a voltage test whenever a puncture occurs in any part of the insulator. It is said to flash over when a discharge of any sort passes all the way from one terminal to the other, since such a discharge would be followed by an arc on a power line.

Local breakdown, either corona or local sparks, while an important symptom, indicating severe local stress, does not constitute a flash-over. The weight to be given to such local breakdown, however, is a matter of judgment.

18. *Rain Tests:*

Water should be sprayed on the insulator at a uniform rate averaging 1 in. (2.5 cm.) depth in 5 minutes, and should be reasonably uniformly distributed over the whole insulator. The rate of precipitation shall be measured by collection of water in a pan at the location of the insulator, the insulator being removed. A fairly satisfactory spray in the form of a fine mist can be obtained by some forms of spray nozzles where pressure is available.

The spray shall strike the insulator at an angle of approximately 45 deg. with the vertical.

The water used shall have a high specific resistance, not less than 5000 megohms per cu. in. (.................................... ohms per cu. cm.). Pure water may often be obtained from condensed steam or melted ice, preferably artificial ice, or rain. Municipal water supplies are often so impure as to seriously impair the performance of the insulator on the wet flash-over.

When insulators are to be used in localities subjected to salt spray or alkali or acid mists, or to conditions producing dew deposits, special tests may be agreed upon.

19. *Puncture Under Oil:*

Tests on a certain percentage of insulator units, ordinarily not exceeding ¼ of one per cent, should be made to determine the ability of the insulator to resist puncture and to measure the uniformity of the product. This test is best made by submerging the insulator in oil.

For this test each suspension insulator unit should be completely assembled with its standard hardware.

With pin type insulators there should be attached to the head of the insulator wires representing the tie and line wires, and a metal pin should be placed in proper manner in the pin hole.

The test voltage should then be applied to the hardware in each case. The puncture value obtained under these conditions should not be less than 135 per cent of the dry flash-over voltage and should where possible be much higher. In the case of suspension units a factor approaching 200 per cent has sometimes been obtained.

The puncture voltage that must be met in the actual tests (§24) should be here specified for each contract, viz., ... volts.

In making the test, apply to the insulator a voltage 30 to 40 per cent below the dry flash-over value and then raise the voltage gradually or by steps, until puncture occurs, at a rate of about 5000 volts per second. The puncture value of porcelain is very sensitive to the length of time voltage near the maximum is applied; the puncture voltage may be lowered as much as 20 per cent by long-continued application of the test voltage. It is well to have a short air gap between each insulator under test and the testing line, that the character of the charging current may be judged by the appearance of the arc.

PIN TYPE INSULATORS

20. *Inspection:*

All parts shall be inspected before assembling.

21. *Routine Tests. Electrical Tests Before Assembling:*

All insulator shells, before being assembled, shall be tested for three minutes at the voltages given in the following table. Should any shell be punctured in the last minute of test, the test will then be continued, after the removal of the punctured piece, until no puncture occurs in one full minute of test. These tests are to be conducted by inverting the parts in pans of water and placing water inside the several pieces, the potential then being applied to the two bodies of water.

NOTE. The water both inside and outside shall be filled to within one quarter of an inch of the highest point to which the later, applied conducting parts, including cement, will extend.

The individual tests in the various shells shall be as follows:

Head. . . . .,	volts
Second Shell. . . . .,	"
Third Shell. . . . .,	"
Fourth Shell. . . . .,	"
Center. . . . .,	"

22. *Routine Tests—Final Electrical Test:*

All completed insulators shall be tested according to one or the other of the three following tests. One of these tests should be definitely specified for each lot of insulators tested under these specifications.

a. The insulators in groups shall be subjected to a voltage steadily applied just below the flash-over voltage for a period of five minutes. The voltage shall be held at such a point that a flash shall occur over some insulator of the set occasionally, but not more often than once in three seconds. This test involves a steady voltage stress and gives an opportunity for the heating up to the puncture point of any spots in the porcelain which may be sufficiently defective. For this test it is therefore objectionable that there should be frequent flashing over, as each flash-over presumably removes the potential from all insulators for one alternation.

If an insulator of the group punctures during the last minute of the test, the test shall be continued until one full minute elapses without a puncture.

b. The insulators in groups shall be subjected to a voltage in excess of the flash-over voltage so that a continuous succession of flashes exists, this being continued for a period of two minutes. This test is intended to introduce the effect of impact and consequently continual flash-over is necessary.

c. The insulators in groups shall be given test (a) above, followed by test (b). The first test may be changed into the second by merely raising the potential without removing the voltage. In this case the time of the second part of the test should be reduced to one minute.

d. This test is the same as test (b) above except that instead of applying this testing to insulators in groups, the insulators shall be tested singly and the voltage continued for a period of 20 seconds.

NOTE. In all the tests (a), (b), (c) and (d), above, it is important that the current be so limited in volume that no power arc shall follow a flash-over, as otherwise the voltage will be substantially removed from the insulators during the continuance of the power arc.

23. *Design Test—Mechanical:*

The following design test shall be made on enough complete insulators, usually not exceeding ¼ of one per cent, to determine the behavior of the design and the uniformity of the product.

The insulators shall be capable of withstanding for 15 seconds without signs of distress a pull of.................... lb. (..................... kg.) applied at the tie-wire groove in a direction at 90 deg. with the axis of the insulator and pin. For the purpose of making this test, the insulator shall be mounted on the pin to be used in service. In case of failure the question as to whether the insulator or the pin is at fault shall be determined by testing again with a solid steel pin turned from a piece of round steel of such dimensions that this piece of steel acting as a pin for the insulator will not bend under the above-mentioned load.

It is desirable that a number of insulators be tested to destruction to show approximately the margin in mechanical strength.

24. *Design Tests—Electrical:*

The following design tests shall be made in enough complete insulators to determine the performance of the type. The insulator shall stand without failure:

(a) A test for *flash-over, dry,* of three times the potential between line wires, applied for one minute.

(b) A test for *flash-over, wet,* of not less than 2 times the potential between line wires, applied for one minute.

(c) Puncture test under oil shall be made as specified under §19 above.

SUSPENSION TYPE INSULATORS

25. *Routine Tests—Electrical Test Before Assembling:*

All insulator shells shall be tested according to one or the other of the three following tests. One of these tests should be definitely specified, for each lot of shells tested under this specification.

a. The shells in groups shall be subjected to a voltage steadily applied just below the flash-over test for a period of three minutes. The voltage shall be held at such a point that a flash shall occur over some shell of the set occasionally but not more often than once in three seconds. This test involves a steady voltage stress and gives an opportunity for the heating up to the puncture point of any spots in the porcelain which may be sufficiently defective. For this test it is therefore objectionable that there should be frequent flashing over, as each flash-over presumably removes the potential from all insulators for one alternation.

If a shell of the group punctures during the last minute of the test, the test shall be continued until one full minute elapses without a puncture.

b. The shells in groups shall be subjected to a voltage in excess of the flash-over voltage so that a continuous succession of flashes exists, this being continued for a period of two minutes. This test is intended to introduce the effect of impact and consequently continual flash-over is necessary.

c. The shells in groups shall be given test (a) above, followed by test (b). The first test may be changed into the second by merely raising the potential at the end of the first test. In this case the time of the second part of the test should be reduced to one minute.

NOTE 1. In all the tests (a), (b) and (c), above, it is important that the current be so limited in volume that no power arc shall follow a flash-over, as otherwise the voltage will be substantially removed from the shells during the continuance of the power arc.

NOTE 2. In making these tests the insulator shells are to be inverted in a pan of water and water placed in the inside. The water both inside and outside shall be filled to within one quarter of an inch of the highest point to which the later-applied conducting parts, including cement, will extend.

27. *Routine Test—Mechanical Test:*

After at least ten days setting of the cement, all units shall withstand for 3 seconds without signs of distress a mechanical pull of .... lb. (................ kg.), in line with the axis of the insulator. Insulators may be given this test after a shorter period of setting, at the risk of the maker.

28. *Routine Test—Final Electrical Test:*

All completed insulator units shall be tested according to one or the other of the three following tests. One of these tests should be definitely specified for each lot of insulators tested under 'this specification.

a. The insulator units in groups shall be subjected to a voltage steadily applied just below the flash-over test for a period of three minutes. The voltage shall be held at such a point that a flash shall occur over some unit of the set occasionally but not more often than once in three seconds. This test involves a steady voltage stress and gives an opportunity for the heating up to the puncture point of any spots in the porcelain which may be sufficiently defective. For this test it is therefore objectionable that there should be frequent flashing over, as each flash-over presumably removes the potential from all units for one alternation.

If a unit of the group punctures during the last minute of the test, the test shall be continued until one full minute elapses without a puncture.

b. The insulator units in groups shall be subjected to a voltage in excess of the flash-over voltage so that a continuous succession of flashes exists, this being continued for a period of two minutes. This test is intended to introduce the effect of impact and consequently continual flash-over is necessary.

c. The insulators in groups shall be given test (a) above, followed by test (b). The first test may be changed into the second by merely raising the potential at the end of the first test. In this case the time of the second part of the test should be decreased to one minute.

d. This test is the same as test (b) above, except that instead of applying this testing to units in groups, the units shall be tested singly and the voltage discharges continued for a period of 20 seconds.

NOTE. In all the tests (a), (b), (c) and (d) above it is important that the current be so limited in volume that no power arc shall follow a flash-over, as otherwise the voltage will be substantially removed from the insulators during the continuance of the power arc.

This test shall be made after the mechanical test above prescribed, §27.

29. *Design Tests—Electrical:*

The following design tests shall be made on enough complete assembled insulators, not exceeding $\frac{1}{4}$ of one per cent, to determine the performance of the type.

(a) A test for *flash-over*, *dry*, of one insulator unit having its normal position in the string and of a complete insulator string consisting of .... units, of .... volts, and.......... volts respectively, applied for one minute.

(b) A test for *flash-over*, *wet*, of a single insulator and of the string, of...... volts and...... volts respectively, applied for one minute.

(c) The puncture test under oil shall be made as specified under §19 above.

It is preferable that the arc-over of the complete insulator when the test voltage is sufficiently raised shall be over the insulator as a whole and shall not be over the individual elements.

30. *Design Tests—Mechanical:*

The following design test shall be made on enough complete insulators, usually not exceeding $\frac{1}{4}$ of one per cent, to determine the behavior of the design and the uniformity of the product.

After at least two weeks setting of the cement, the insulators tobe tested shall withstand for 15 seconds without signs of distress a pull of .... lb. (................ kg.) in line with the axis of the insulator.

It is desirable that a number of these insulators be pulled to destruction to show approximately the margin in mechanical strength.

APPENDIX

The following tests are recommended as desirable where appropriate. They are not incorporated in the above specifications as experience with them is not yet sufficiently broad.

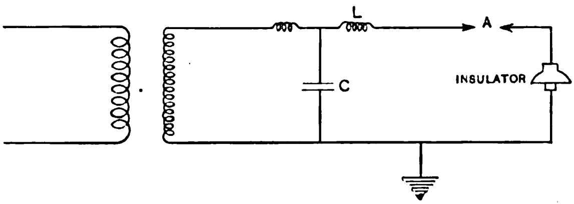


FIG. 1

31. *Uniformity Puncture Test:*

Twenty-two single insulators, chosen at random from stock, which have passed all routine tests, shall each in turn be punctured under oil as provided for oil tests in §19 above.. Any twenty of these values of puncture voltage shall then be selected by the maker. The difference between the maximum and minimum of these twenty puncture voltages must not be more than 20 per cent of the average voltage. This test should be repeated with one or more additional groups of 22 disks, not exceeding in the aggregate $\frac{1}{4}$ of one per cent of the total, enough to determine the uniformity of the product. In case of failure of the lot to pass this test, the other insulators from the same burnings shall be tested as specified under §28, but for a period 5 times that there specified.

32. *Design Test—Impulse Test:**

Ten units shall be selected at random. Each of these disks shall be connected in turn to the impulse circuit shown in Fig. 1.

*For an example of the application of such a test see paper by Imlay and Thomas, TRANS. A. I. E. E. Vol. XXXI, 1912, p. 2121.

The gap A shall be set at three or preferably four times the arc-over voltage of a single unit. The voltage shall be increased until gap A sparks over, when the circuit shall be immediately opened by breaker or the voltage otherwise removed. This shall comprise a " stroke." Such strokes shall be repeated on each unit or string of units up to .... strokes or until puncture occurs. Preference shall be given to the design or make of insulator showing the greatest uniformity and the highest resistance to puncture. Referring to Fig. 1, the shunt condenser capacity shall be equal to that of an air plate condenser having from seventy-five to one hundred square feet surface on each plate and a spacing equal to 25 per cent more than the sparking distance of the voltage used. The connections from the condenser to the insulator should be as short as practicable.

NOTE: The above test will show, in a general way, the probable effect of surges, lightning, etc., on the life of the insulator, as well as the uniformity of the porcelain. While there is not sufficient experience with this test to secure a numerical measure of the number and sort of strokes that must be withstood by the insulator to insure a puncture-proof product, the test as outlined above is very important in competitive tests.

33. *Design Test—Combined Mechanical and Electrical Test:*

The following design test should be made upon enough insulators to determine the performance of the design and the uniformity of the product.

An insulator placed in an insulated testing machine and impressed with a voltage just under or just over the flash-over voltage (as may be agreed upon), shall be subjected to a gradually increasing mechanical pull until puncture occurs.

The insulator should not puncture at less than twice, or, preferably, three times the maximum pull to which the insulator is to be subjected in service, as fixed in §6 above.

34. *Uniformity—Brittleness Test, Applicable Especially to Suspension Insulators:*

The following uniformity test should be made upon enough insulator units to determine the performance of the design and the uniformity of the product.

A completed insulator unit which has passed all routine tests shall be placed in ice water and the temperature of the water raised to boiling. The heating should not begin until after the insulator has been in ice water 15 minutes to permit all parts

to come to the same temperatures. The water should then be heated at a uniform rate of about one degree cent. per minute. After remaining at boiling temperature for 30 minutes the unit may be removed and should afterward be tested either by the measurement of its insulation resistance, using one or two thousand volts for the measurements, or by the standard routine electrical test (§28), or both.

35. *Percentage of Failure in Routine Tests.* The percentage of punctures in the electrical tests is a rough measure of the burning of the porcelain and the care in manufacture. A relatively large percentage of failures, perhaps over 5 per cent, suggests under-firing. It is recommended that the following modification be applied to routine tests §22 and §28:

"When the percentage of punctures in any group of insulator units or shells under test simultaneously, exceeds 5 per cent, the length of the time of application of the voltage shall be doubled for that group".

Presented at the 296th meeting of the American Institute of Electrical Engineers, Pittsfield, Mass., May 29th, 1914.

DELTA AND Y CONNECTIONS FOR RAILWAY TRANSMISSION AND DISTRIBUTION

BY CASSIUS M. DAVIS

ABSTRACT OF PAPER

Transformer connections under the following three conditions are discussed:

The railway; (1) purchases power; (2) builds and operates the generating and transmission systems; (3)purchases power and in addition builds and operates a secondary transmission system.

The choice between delta and Y connection is frequently determined by purely economic considerations. However, it is common practise to use the delta connection on both the high- and low-tension sides of transformers, except in the case of six-phase converters, where the diametrical connection on the low-tension side is the rule. Synchronous converter substations employing two machines in series for high-voltage d-c. railways, are frequently operated from single banks of transformers, which have double windings on the low-tension sides. Methods of starting have little effect upon transformer connections except in the case of six-phase converters. Transformer connections are seldom important electrically in single-phase and three-phase railway systems. A secondary distribution system may at first be delta connected and later changed over to Y connection to obtain better voltage regulation.

THERE are three general problems which present themselves for any railway system. They are classed as follows:

1. The railway purchases power.
2. The railway builds and operates the generating and transmission systems.
3. The railway purchases power and in addition builds and operates a secondary transmission system.

These conditions to a certain extent affect the choice of transformer connections, the use of delta or Y frequently being determined from purely economical standpoints. That is, it may be cheaper to install transformers with delta-connected primaries for a given synchronous converter than with Y-connected primaries.

A further condition, which may or may not have a bearing on the system of connection, is the fact that interurban lines and railway electrifications require substations which are spaced

at an ever increasing distance from the generating station. They are frequently tapped off the same transmission line.

1. *Power Purchased by the Railway.* The railway has no choice as to the manner in which the supply system is connected. It must accept the power from either a delta or a Y-connected transmission line, grounded or ungrounded.

General practise favors the delta connection on the high-tension side of the substation transformers regardless of the arrangement of the transmission system. The principal argument is that a three-phase bank of transformers may be operated open delta in emergencies at 58 per cent of its total normal output.

The connection on the low-tension side depends upon the type of distribution and on the kinds of transforming or converting apparatus.

For synchronous-converter substations with three-phase converters the delta connection is usual. This holds for machines of all voltages.

For synchronous-converter substations with six-phase converters the diametrical is the rule, since with either the double delta or the double Y, two secondary windings are required, while the diametrical connection needs but one secondary winding.

Synchronous-converter substations operating two machines in series for voltages from 1200 to 2400, and when supplied from single transformer banks, always have double secondaries connected delta for three-phase converters, and diametrical for six-phase machines.

Railway work seldom requires the neutral to be brought out. Where it is required, however, the Y, the "zig-zag" or the diametrical connection must be used with proper provision for starting.

Motors for motor-generator sets may receive power from transformer secondaries connected either delta or Y. There is little choice between the two connections. Substations employing motor-generator sets frequently have a low-tension a-c. bus which is fed from transformers where the secondary connection is governed by conditions extraneous to railway operation. For example, the low-tension a-c. bus may form a part of an a-c. network, the neutral of which it is desirable to ground.

The methods of starting are controlled somewhat by the

secondary connection. Synchronous motors and converters are conveniently started from reduced voltage taps. If the transformers are delta connected, starting can easily be accomplished on open delta. If they are Y connected, the machines can be started at reduced Y voltage. With six-phase converters, the starting connections become very complicated with either the double delta or the double Y connection, especially with the machines of large output. Synchronous converters are seldom started by means of compensators for the reason that each converter is usually provided with its own bank of transformers, the taps of which are far less expensive than a separate compensator.

Starting from the d-c. side, or by means of a direct-connected starting motor, obviously has no bearing on the transformer connections and hence is omitted from this discussion.

The possibility of grounds and short circuits on the trolley or third rail have no effect upon the choice of transformer connections.

Since energy for single phase railways is usually transmitted single-phase, the question of transformer connections does not come up for discussion. Even where the transmission is polyphase, the low-tension distribution for a single-phase railway system is taken from the transmission line through single-phase transformers. Thus, as far as the present discussion is concerned, there is no choice involved between delta and Y.

Either delta or Y connections may be used for three-phase railways. The choice would be governed by conditions existing in each individual case.

2. *Generating System Built and Operated by the Railway.* This problem involves the general question of delta versus Y connection. It is not necessary to go into a discussion of the advantages and disadvantages of either system since these points are brought out in other papers presented at this meeting. A railway load does not differ in essentials from any other load, and the same arguments relative to the choice of system apply here as well as to any other type of load.

In any system adopted, due provision should be made for extensions. This is especially true in railway electrifications where usually only a few miles constitute the initial electrification which ultimately may extend several hundred miles. Transmission lines for this type of load may be tapped at frequent intervals. This fact, it would seem, would tend to prevent,

or at least to mitigate, any tendency toward transmission line disturbances. Any high-frequency discharge or surge would be broken up in passing the various substations.

3. *Secondary Distribution Built and Operated by the Railway.* The railway frequently requires a secondary distribution system consisting of a line along the right-of-way. For moderate voltages, the line may be connected either delta or Y, with little choice between the two from an electrical viewpoint. It often may be advisable to economize on line material when first installed, and connect the transformers in delta until the load increases to such a point that better line efficiency and regulation are advantageous. Then the transformers can be connected Y for a 73 per cent increase of voltage. This of course necessitates transformers insulated for Y-connected circuits, and requires proper line insulators.

Conclusions

1. In general the same arguments for delta and Y connections as to reliability of operation, grounds, abnormal voltages, high-frequency disturbances, etc., apply as well to railway systems as to other systems and the factors which govern the choice of connection for one system govern the choice for all.

2. The low-tension sides of substation transformers are usually delta connected, except for six-phase synchronous converters, and except where specific local conditions demand a Y connection for obtaining the neutral.

3. Six-phase synchronous converters are usually supplied from delta-diametrical connected transformers. The Y-diametrical connection is also possible.

4. The choice of connection for low-tension distribution systems between substations is largely dependent upon commercial economy rather than upon purely electrical considerations.

To be presented at the 300th Meeting of the American Institute of Electrical Engineers, Philadelphia, Pa., October 12, 1914, under the auspices of the Committee on Use of Electricity in Marine Work.

ELECTRICAL EQUIPMENT OF THE ARGENTINE BATTLESHIP "MORENO"

BY H. A. HORNOR

ABSTRACT OF PAPER

This paper describes the electrical installation of one of the two Argentine battleships building in this country and now nearing completion. The methods of installation and distribution of energy; the extensive application, far surpassing any vessel so far constructed in this country, and the results secured by departure from present practise; all these are concisely recorded.

Detailed descriptions are given of important and unusual equipments such as steering gear, anchor windlass, searchlights, gyro-compass, etc., etc.

THE MORENO is one of the two super-dreadnoughts building in this country for the Argentine Republic. The general characteristics of the *Moreno* are as follows:

Length over all, 594 ft. (181 metres); displacement, 27,566 tons (28,000 metric tons); draft, 27 ft. 9 in. (8.46 meters); width 98 ft. 0 in. (29.89 meters); main battery, twelve 12-in. (304.8 mm.) breech-loading rifles mounted in six turrets; torpedo defense battery, sixteen 4-in. (101.6 mm.) and twelve 6-in. (152.4 mm.) breech-loading rifles.

It is the purpose of this paper to describe in general the electrical equipment of this vessel. The applications are so numerous and varied that only the unusual equipments have been selected for detailed comment. By reason of the confidential nature necessarily involved in military applications, all reference to such has been omitted. As all installations of this character are divided into three general systems, namely, lighting, power, and signaling, this grouping will be followed.

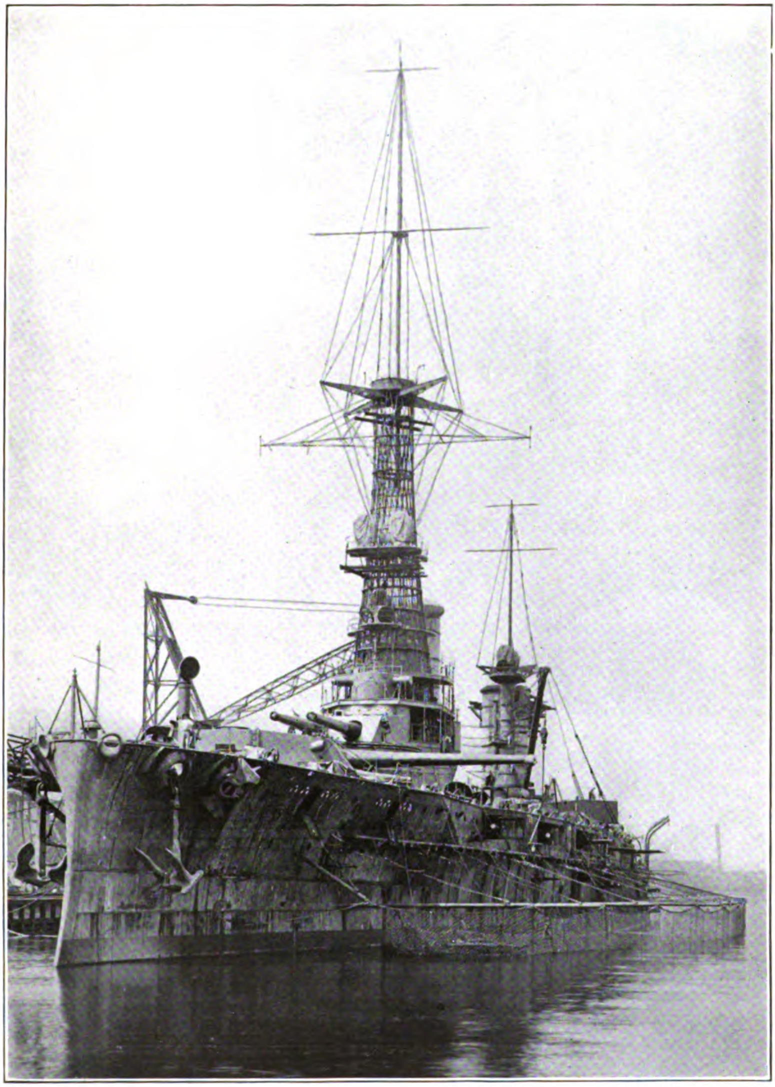
GENERATING PLANT

Power for all purposes is supplied by four 375-kw. turbo-generators of the horizontal type. Two of these machines are located forward and two aft on the lower platform deck below armor. Adjacent to each dynamo room is a distribution room

in which is located a main distribution switchboard for the control of the two units and the supply circuits. On the gun deck is a third dynamo room containing two Diesel oil-engine-driven generators of 75 kw. capacity for harbor use when fires are drawn.

The 375 kw., 230-volt, 1500-rev. per min. turbo-generators are of standard marine design capable of operating at a steam pressure of 220 lb. per sq. in. (15.4 kg. per sq. cm.), condensing at a normal vacuum of 28 in. (71.1 cm.) and also non-condensing with 5 lb. (2.27 kg.) back pressure. The turbine is of the well-known Curtis horizontal, two-stage type, fitted with automatic valve gear, inertia governor, and an emergency valve for automatically closing when the speed exceeds 10 per cent of normal. Forced lubrication is provided for the main bearings, and the oil is cooled by water circulation. The generator is a compound wound, direct-current, commutating-pole type, mounted on the same bedplate and directly coupled to the turbine. The magnet frame is circular in form and divided horizontally. The generator is capable of standing a $33\frac{1}{3}$ per cent overload for two hours and 50 per cent overload for five minutes.

The Diesel oil-engine-driven sets are rated at 75 kw., 375 rev. per min., 230 volts. The generator is directly connected to the oil engine but not mounted on the same bedplate. The generators are designed in a similar manner and are capable of functioning in the same way as the main generators above described. The Diesel oil engine is guaranteed to develop 120 b.h.p. normally and also 180 b.h.p. overload. The engine is vertical, four cycle, single acting, and is provided with four power cylinders and one air-compressor. The engine is started by means of compressed air at about 650 lb. per sq. in. (45.5 kg. per sq. cm.) obtained from storage tanks. During the starting of the engine the cooling water is gradually started and will be in full flow when normal ignition has been established. The plunger for the fuel oil pump is operated by an eccentric attached to the vertical shaft of the valve gear drive. An auxiliary cooling water pump and fuel oil pump are also provided. These auxiliaries are electrically driven, the former by a 2.7 h.p. motor and the latter by a 1.75 h.p. motor. The fuel oil used may be fairly heavy, even heavier than 20 deg. Beaumé at 60 degrees fahr., so long as it flows readily and can be handled by the fuel oil pump. The heat value of the oil should not be less than 18,500 B.t.u. (4662 kg. cal.) per pound.



[HORNOR]

FIG. 1—*Moreno* AT THE YARDS OF HER BUILDERS, AUGUST 19, 1914

Installation and Distribution

Current is carried to all the various systems on a two-wire metallic system, by means of rubber covered, (44 per cent pure Para) lead-sheathed, steel-armored conductors. These cables are clipped singly, or in groups, to the ship's structure or clipped to special sheet steel pans supported from beam to beam or fastened to the plating. Water-tight fittings are provided wherever the cables terminate and when passing through water-tight bulkheads. Twin conductors are employed from 3256 cir. mils. up to 30,856 cir. mils., and beyond this single conductors up to 373,737 cir. mils. All the conductors in this installation are stranded, lead-covered, steel-armored, with the exception of the flexible leads in the turret trunks and special brass-covered wire and three-conductor rubber-insulated wires, called by the German trade name "Kuhlo," used for branch leads in the officers quarters and staterooms.

Besides the two main distribution switchboards located adjacent to the two dynamo rooms, there are two auxiliary distribution boards located one forward and one aft; a control board for the oil engine generators; and a combined distribution and control board for the search-light balancer sets. These boards are all interconnected so that the supply will always be available. The interconnecting circuit breakers are fitted with interlocking devices and reverse-power relays so that by no possibility will the generators in one room be thrown in parallel with those in another room. The distribution switchboards are designed with separate busbars for positive lighting and positive power and a common negative. It is possible, therefore, to divide the load in various ways between the different dynamo rooms. To facilitate this, indicating voltmeters and ammeters are connected in the local and remote circuits and a diagram of the busbar connections is painted in grooves on the front face of the oil-finished slate panels.

Lighting System

The vessel is provided with approximately 3000 fixtures. The design is similar to the usual water-tight vapor-proof globe type used in marine work. The screw-base lamp socket is, however, made solid instead of a spring, a composition-insulated base provided instead of porcelain and the globe is flanged and held in place by the guard instead of being screwed into the base. In the magazines and shell rooms, specially guarded fixtures con-

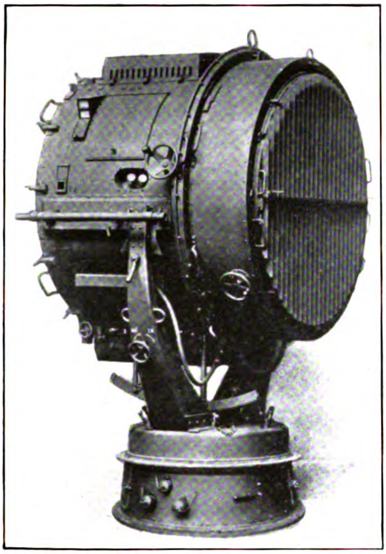
taining two lamp sockets are installed. The lamps in these fixtures are connected to different circuits so that the failure of light in these compartments may be averted. Both carbon and tungsten incandescent lamps are furnished; the former in sizes of 35 watts and 60 watts, clear; the latter in sizes of 32 watts, clear frosted and tubular. A special fixture containing a 250-watt tungsten lamp and provided with a reflector is arranged for portable connection in the engine, boiler, and dynamo compartments. This same type of fixture is also employed for coaling booms, propellor booms, and gangway lighting.

Life tests of the 220-volt tungsten incandescent lamps showed as high as 98 to 101 per cent of the initial c.p. after 1162 to 972 hours burning. The spherical reduction factor for the tubular lamp was 0.96 and for the pear-shaped bulb (s-19) was 0.914.

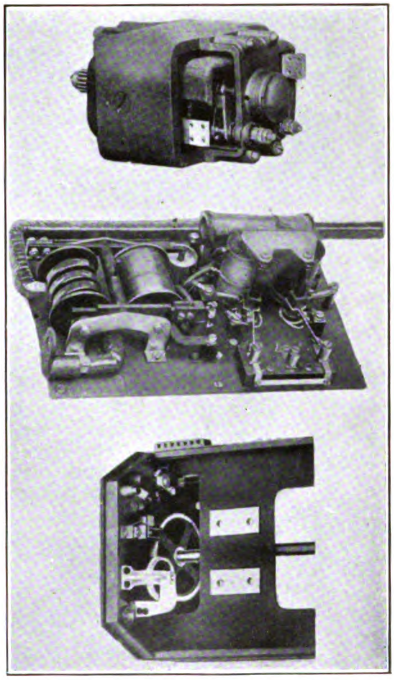
The 38 lighting feeders are divided into three circuits; one for general illumination under cruising conditions, one for white battle purposes, and one for blue battle purposes. In this latter circuit the globes are of a deep blue color making the light invisible at a short distance. The distribution of the small lighting units has been made with due regard for cross circuits so that no general spaces of the vessel may be put in darkness by the blowing of a fuse or any other failure of an individual circuit. The distribution of these lights was based on the number of candle-power per cubic foot of space to be lighted; thus in the Admiral's quarters a maximum of 0.08 c.p. per cubic foot was required and in the storerooms a minimum of 0.01 c.p. per cubic foot. Each officer's stateroom of ordinary size is provided with one fixed light, one portable light, and an outlet for a 12 inch portable electric fan.

As shown in the diagram (Fig. 2) the feeders are led from the main distribution switchboard to approximately their center of distribution. Mains are then branched from the feeder, and terminate in fused distributing panels of water-tight construction. From these panels branches are lead off to the individual lights. Not more than four lights (one ampere) are allowed to depend upon the same fuse. The branch leads are all of 1.6 mm. (3250 cir. mils) twin conductor.

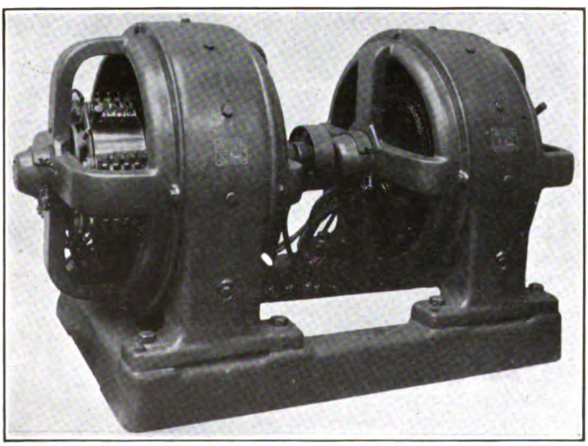
For night battle purposes the vessel is equipped with 12 motor-operated, remote-electrically-controlled 110 cm. (43.3 in.) searchlights and one portable signaling projector of 35 cm. (13.77 in.). As these projectors operate more satisfactorily when supplied with 110 volts, it was considered advisable to



[HORNOR]
FIG. 3—ELECTRICALLY CONTROLLED SEARCHLIGHT



[HORNOR]
FIG. 4—SEARCHLIGHT LAMP MECHANISM



[HORNOR]
FIG. 8—SEARCHLIGHT BALANCER SET

transform the 220-volt supply circuit through special balancer sets. Two such machines are installed in the vicinity of the oil engine dynamo room wherein is located the control switch-board for them and the distribution board for the searchlight feeders. Each balancer set is rated at 70 kw. 1000 rev. per min. 110 to 220 volts, the full load current on the neutral being 637 amperes. They are compound wound, and the series and shunt coils are connected so that they act accumulatively on the generator and differentially on the motor. The series and shunt coils in one frame are connected across the armature of the other frame for the purpose of producing constant voltage at each end. The

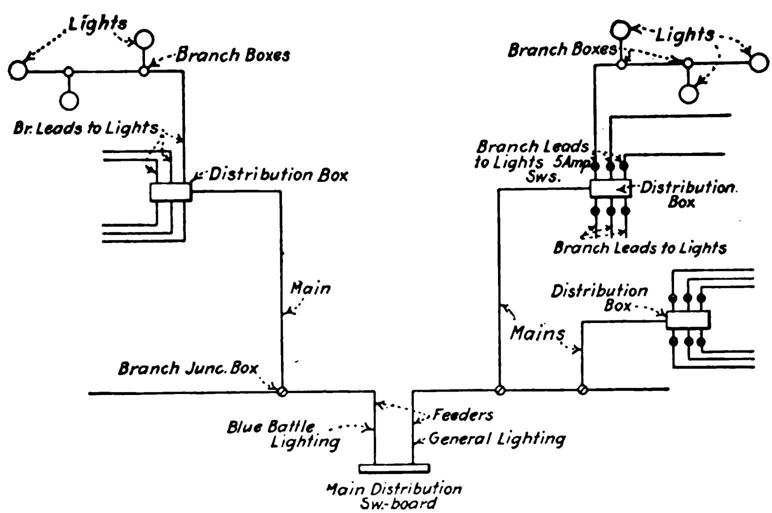


FIG. 2—DISTRIBUTION DIAGRAM

sets will maintain a difference of potential not in excess of seven volts under any conditions of load with an impressed e.m.f. of 220 volts. Either end of these sets operate as a motor or generator as may be demanded by the load.

Only a brief description can be given of the searchlights proper. Fig. 4 shows the lamp mechanism. Fig. 5 is a wiring diagram when the carbons are apart. Fig. 6 the same with the carbons together, and Fig. 7 gives curves illustrating the time saved by the employment of a shunt motor for automatically adjusting the carbons in preference to a compound wound motor. The twelve 110-cm. (43.3 in.) searchlights are similar in every respect except that one projector is equipped with a remote-electrically-

controlled signaling shutter. The lamp mechanism consists of a small electric motor which functions through gearing and so moves the carbons. The field and armature of the motor are controlled by a differential relay and two auxiliary relays which

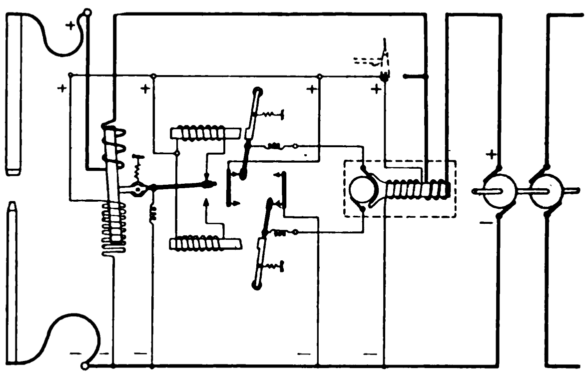


FIG. 5—DIAGRAM OF LAMP CONNECTIONS—CARBONS APART

cause the armature either to stop or rotate to right or left. The first takes place with the current and voltage normal, the second when the amperage is too high and the voltage too low, and the third when the last condition is reversed. Besides the regular

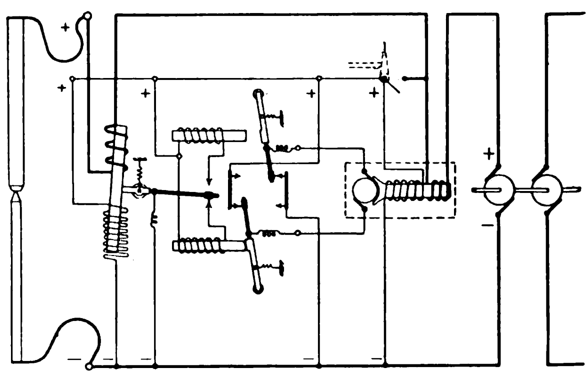


FIG. 6—DIAGRAM OF LAMP CONNECTIONS—CARBONS TOUCHING

field winding there is an additional winding on the motor field to carry the full lamp current. This produces a strong field when the voltage across the arc falls below normal and furnishes a dynamic braking effect for retarding the movement of the motor armature. For signalling purposes the searchlights are equipped

with iris shutters similar to camera shutters. These are all manually operated except one in which latter case a venetian blind shutter, remotely controlled, is also provided. The optical arrangements are such as to provide rapid means for changing over from a dispersed to a closed beam of light. This is accomplished by means of a double disperser, consisting of two parallel systems of plano-convex cylindrical lenses, which may at will be drawn together or separated. A sighting telescope at-

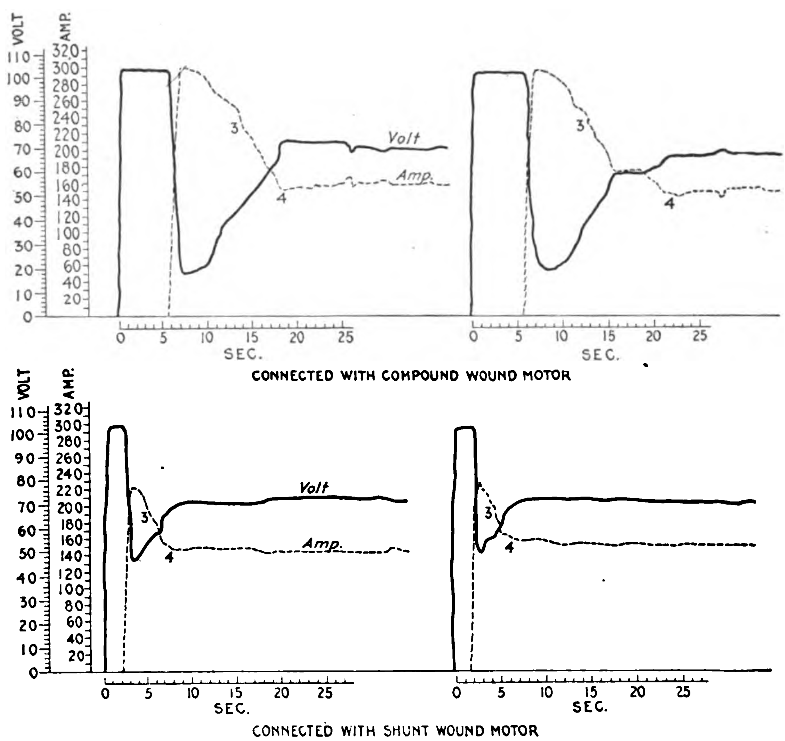


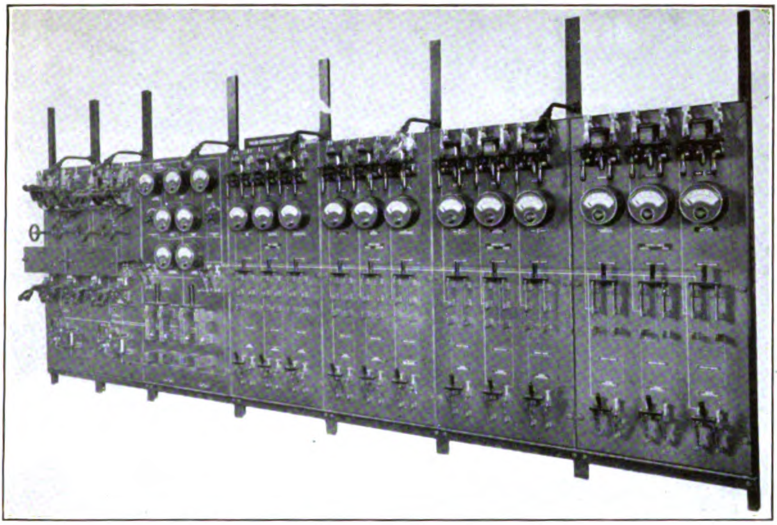
FIG. 7—TIME DIAGRAMS OF SEARCHLIGHT LAMP MOTORS

tached to the side of the drum; a complete lamp telegraph indicating the positions of the searchlight at the controller; and a set of electrical instruments, consisting of a voltmeter and ammeter, are furnished with each searchlight. A complete horizontal cycle of the searchlight may be accomplished either in 28 seconds or approximately 15 minutes by means of the electric remote control. This control may be detached and the mechanism operated locally by hand.

Power System

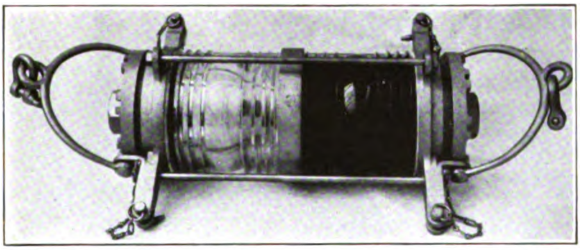
The following list shows the extensive applications of the electric power and gives the rated load for each equipment. It should be borne in mind that these numerous equipments have their special uses and are brought into action in general upon different occasions. Such systems as the ventilation system, sanitary pumps, etc., etc., are continuously in service; but on the other hand the deck machinery such as boat booms, deck winches, coaling winches, etc., are only used when in port coaling, handling small boats, etc. In like manner the turret machinery is only used under battle conditions or for practise drills.

No.	Equipment	Rated horse power	Total horse power
2	Boat Boom Hoisting..	50.	100.
2	Boat Boom Topping ..	30.	60.
4	Deck Winches.......	35.	140.
16	Ammunition Hoists...	3.	48.
6	Ammunition Hoists...	5.	30.
12	Forced Draft Blowers.	35.	420.
1	Anchor Windlass.....	100.	100.
1	Capstan	100.	100.
2	Coaling Winches.....	150.	300.
1	Steering Gear........	150.	150.
3	Bilge Pumps...... ...	70.	210.
14	Bilge Pumps.........	35.	490.
2	Searchlight Balancer Sets..............	93.	186.
1	Fire Pump...........	60.	60.
2	Fresh Water Pumps..	6.	12.
2	Sanitary Pumps.. ...	35.	70.
1	Drainage Pump.......	3.	3.
2	Thermo Tank Pumps.	35.	70.
3	Turbine Lifting Gear.	30.	90.
1	Laundry.............	6.	6.
1	Printing Press....	0.25	0.25
3	Speed Signal Balls....	0.5	1.5
1	Cake Mixer....	1.	1.
1	Dough Mixer........	2.5	2.5
1	Diesel Engine Oil Pump..........	1.75	1.75
1	Diesel Engine Cooling Water Pump..	2.7	2.7
12	Turret Turning.......	25.	300.
12	Gun Elevating...	15.	180.
13	Turret Hoists........	7.5	97.5
5	Turret Hoists........	12.	60.
1	Dryer Room.........	1.	1.
1	Roentgen Ray Equipment..............	5.	5.
1	Vacuum Cleaner.. ...	0.33	0.33
1	Electro - Mechanical Hammer..........	5.	5.
2	Torpedo Air Compressors..............	90.	180.
5	Refrigerator Pumps...	19.5	97.5
5	Brine Pumps.........	3.5	17.5
2	Ozonizer Motor-Generators............	1.3	2.6
2	Ozonizer Pumps......	0.5	1.
9	Elevators....	4.	36.
1	Wireless Motor-Generator..	18.	18.
2	Alternating-Current Motor-Generators..	37.	74.
1	Dish Washer..	1.	1.
1	Meat Slicer..........	0.5	0.5
1	Meat Chopper........	1.	1.
1	Potato Peeler...	1.	1.
1	Ice Cream Freezer....	1.	1.
1	Egg Beater..........	2.	2.
1	Extension Lathe.....	3.	3.
1	Tool Room Lathe, 14 inch...........	0.75	.75
1	24 inch Shaper...	3.	3.
1	30 inch Radial Drill...	2.5	2.5
1	16 inch Sensitive Drill.	0.75	0.75
1	14 inch Tool Room Lathe............	0.75	0.75
1	Grindstone..........	1	1
1	46 inch Boring Mill...	3	3
1	Cutter and Grinder...	1	1
1	Tool Room Lathe 14 inch	0.75	0.75
1	Sensitive Drill 16 inch.	0.75	0.75
1	Lathe for Armorer's Workshop.........	0.75	0.75
1	Shaper for Armorer's Workshop.........	2.	2.
1	Sensitive Drill for Armorer's Workshop..	0.75	0.75
1	Forge Blower........	0.75	0.75
1	Foundry Blower......	5.	5.
1	Athletic Horse.......	2.	2.
1	Moving Picture Machine..	17.6	17.6



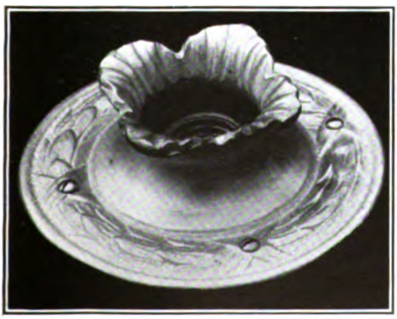
[HORNOR]

FIG. 9—SEARCHLIGHT DISTRIBUTION SWITCHBOARD



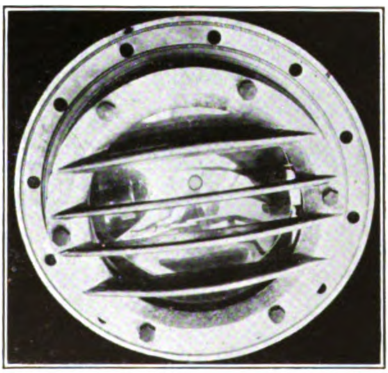
[HORNOR]

FIG. 9a—NIGHT SIGNAL SET LANTERN



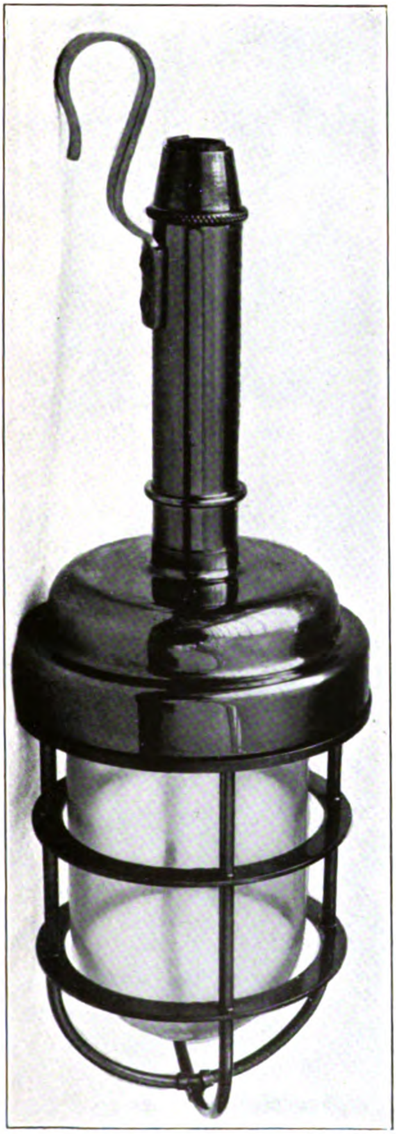
[HORNOR]

FIG. 9b—SILVER FIXTURE—ADMIRAL'S QUARTERS



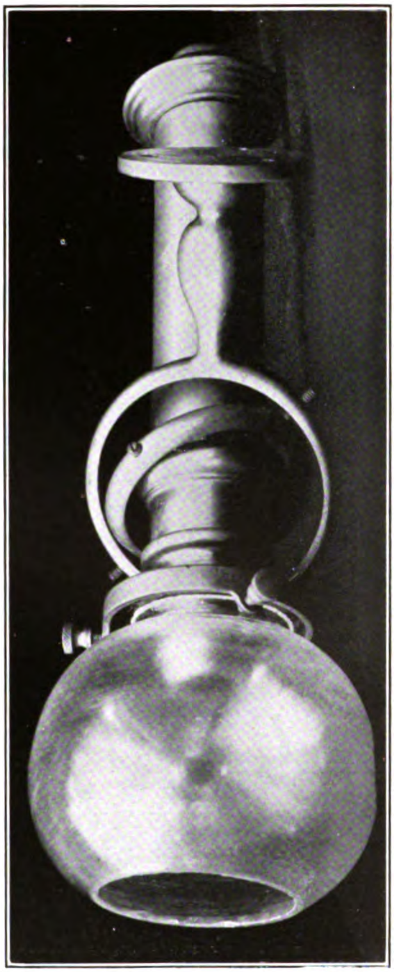
[HORNOR]

FIG. 9c—BULKHEAD BUNKER FIXTURE



[HORNOR]

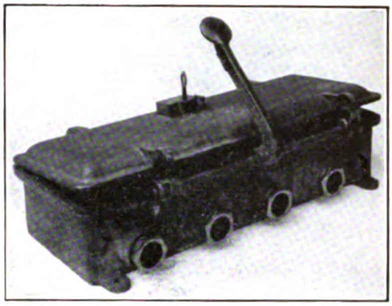
FIG. 9d—WATER-TIGHT PORTABLE LAMP



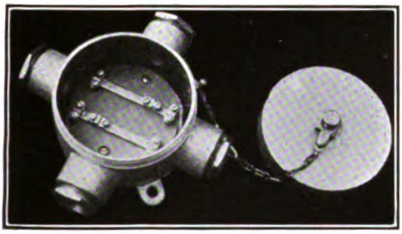
[HORNOR]

FIG. 9e—BRACKET FIXTURE

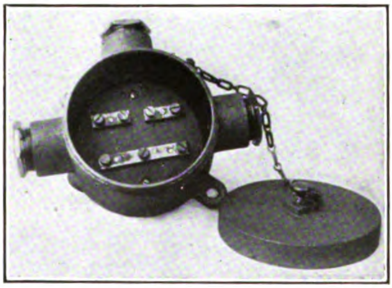
[HORNOR]
FIG. 9f—DESK PORTABLE



[HORNOR]
FIG. 9g—SELF-CLOSING DISTRIBUTION BOX



[HORNOR]
FIG. 9j—FEEDER JUNCTION BOX, 4-WAY



[HORNOR]
FIG. 9h—WATER-TIGHT BRANCH JUNCTION BOX—THREE-WAY

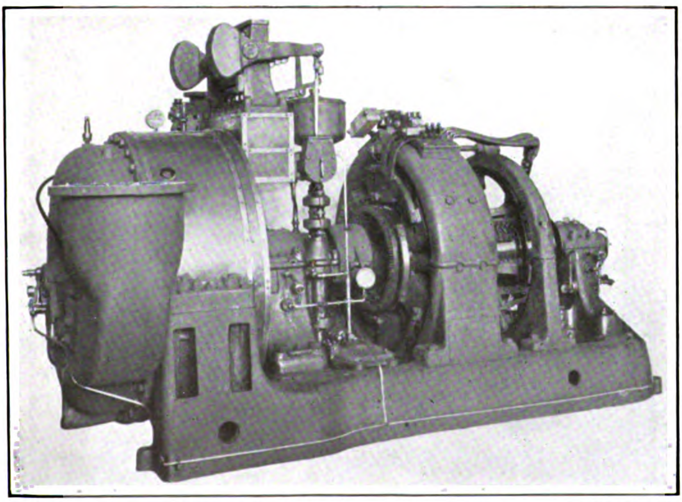


FIG. 12—375-KW. GENERATOR [HORNOR]

No.	Equipment	Rated horse power	Total horse power	No.	Equipment	Rated horse power	Total horse power
9	600-cu. ft. Ventilation Fans	4.	36.	2	5000 cu. ft. Ventilation Fans	6.75	13.5
9	1600 cu. ft. Ventilation Fans	1.	9.	7	6000 cu. ft. Ventilation Fans	3.75	26.25
1	1600 cu. ft. Ventilation Fan	2.	2.	5	6000 cu. ft. Ventilation Fans	7.	35.
6	2500 cu. ft. Ventilation Fans	1.5	9.	2	8000 cu. ft. Ventilation Fans	5.	10.
24	2500 cu. ft. Ventilation Fans	2.75	66.	6	8000 cu. ft. Ventilation Fans	9.	54.
3	2500 cu. ft. Ventilation Fans	3.5	10.5	2	10,000 cu. ft. Ventilation Fans	6.25	12.5
4	5000 cu. ft. Ventilation Fans	3.25	13.	3	12,000 cu. ft. Ventilation Fans	7.5	22.5
6	5000 cu. ft. Ventilation Fans	6.	36.	2	15,000 cu. ft. Ventilation Fans	10.	20.

As shown in the cable scheme for power distribution (Figs. 10 and 11) the feeders from the main distribution switchboards in some cases are lead directly to the motor starting panel, in others they are branched into mains and in others they are lead to special distribution panels. This latter is so in the case of the four-in. (101.6 mm.) and six-in. (152.4 mm.) ammunition hoists, the searchlights, and the 12-in. (304.8 mm.) turrets. The turret distribution panel is located on the revolving part of the turret and is encased in a water-tight steel box.

As shown by the illustration a variety of motor types are used, viz: open, semi-enclosed, fully-enclosed, and enclosed-ventilated. The small motors up to 10 h.p. are regulated by simple starting and field control panels. Above 10 h.p. drum controllers are employed. On the very large equipments performing special service and requiring 50 to 150 h.p. contactor control with dynamic braking is provided.

Steering Gear

The electrical equipment is designed as an auxiliary to the steam steering engine, operates through the same telemotor gear on a "follow-up" system, and furnishes only sufficient power to carry the rudder from hard-over to hard-over in 40 seconds, which is half the time requirement of the steam gear. The motor is of the commutating pole, open type, compound-wound, rated at 150 h.p., 400 to 600 rev. per min., 220 volts. The controlling appliances comprise a master controller and limit switch mounted in one case, a contactor panel and the necessary field and armature rheostats operated by the same. In the

master controller are two cylinders provided with rings; these make electrical contact with plungers; one of these cylinders is for the controller, the other for the limit switch. Both cylinders turn freely on their supporting shafts. The controller cylinder operates through a connecting rod from the operating shaft of the steering gear. The limit switch cylinder operates through a sprocket chain from the main steering gear shaft. The differential gear, or "follow-up" device, is located between the two cylinders and is designed to turn the controller cylinder off by motion of the main shaft of the steering gear which turns the limit switch.

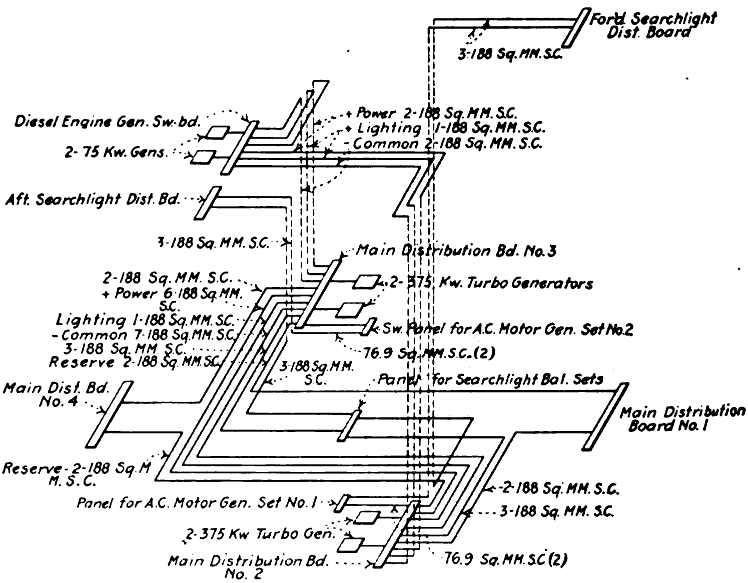


FIG. 10—DIAGRAM OF POWER DISTRIBUTION

The latter strengthens the field of the motor when the rudder is displaced more than 10 deg. from the midship position. The mechanical connections are such that the motor will stop when the rudder has reached the angle for which the steering wheel has been turned. The motor field cannot be weakened until all of the accelerating contactors have closed, after which the controller will maintain full field until it has been turned through an angle corresponding to 3 deg. movement of the rudder from starting position, and intermediate field from 3 deg. to 5 deg., after which the motor will run at weak field until the rudder has

reached 10 degrees from the midship position. Mounted upon the contactor panel are 10 armature contactors, two field contactors, one disk brake contactor, two counter e.m.f. contactors, an overload relay, a double-pole, fused, control switch, and a single-pole testing switch. The overload relay controls four of the five accelerating circuits whereby they operate, resistance is introduced into the armature circuit, and the field rheostat short-circuited so that the motor is protected against continued overload without being actually stopped. In this manner accidentally losing control of the rudder cannot occur. The limit switch is arranged to stop the motor at the 35-deg. position of the rudder. Dynamic braking is provided in connection with the electro-

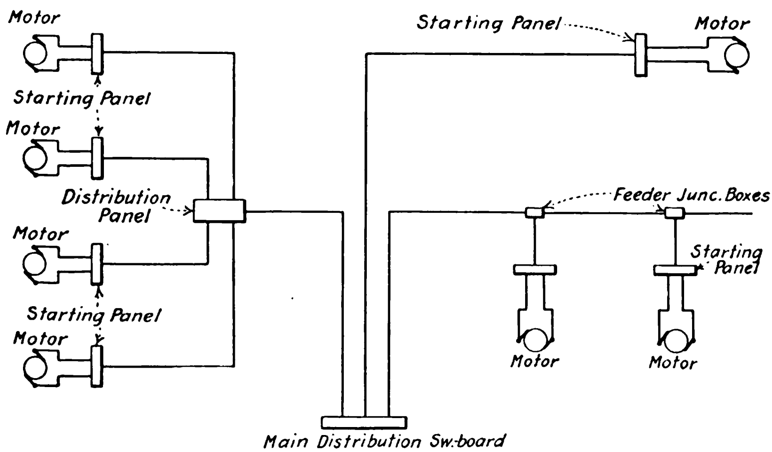


FIG. 11—CABLE SCHEME FOR POWER DISTRIBUTION

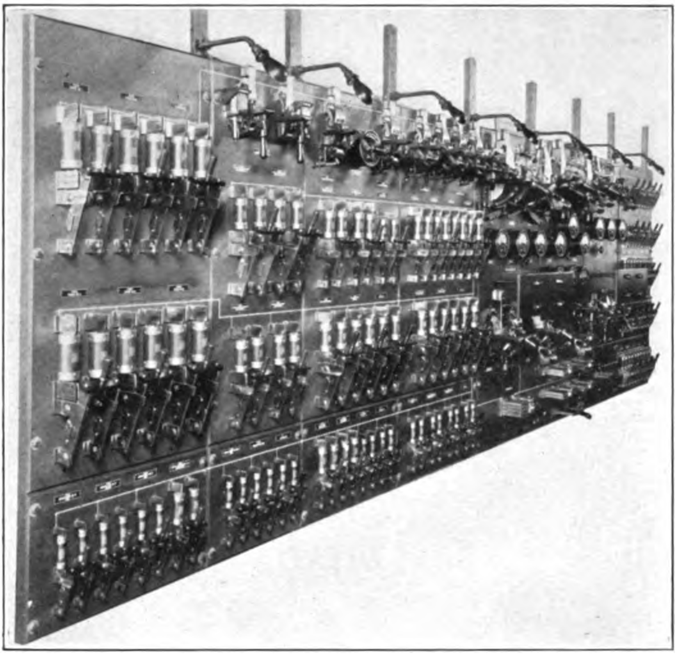
mechanical disk brake in order to provide prompt stopping. The rudder can be turned at slow speed throughout its travel, providing the steering wheel is turned slowly, thereby permitting the motor to turn the controller cylinder backward as fast as it is turned forward by the steering wheel. This may be accomplished while the controller cylinder moves back and forth between limits corresponding to 2.25 degrees motion of the rudder, as the motor will start with a motion of cylinder equivalent to 0.75-deg. movement of the rudder and the field will be weakened with 3-deg. similar motion.

TURRET HOISTS

The turret turning and gun elevating gear are operated by constant-speed motors, and speed variations are accomplished

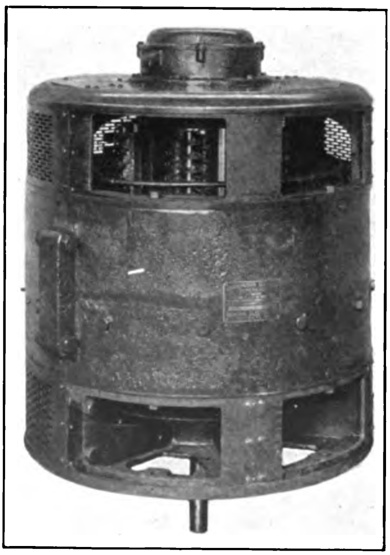
by mechanical means. Ventilation blowers in the turrets are similar to the regular hull ventilation fans except for increased pressure. The independent hoists complete the electric power equipment of the turrets. The main ammunition hoists are operated by hydraulic power and the electric hoists are provided as an auxiliary. Two upper hoists are fitted in each of the six turrets. These are operated by 7.5-h.p. motors. One lower hoist is fitted in each turret of which one is operated by a 7.5-h.p. motor and the others 12-h.p. motors. As these equipments are generally similar in their operation only the 12-h.p. lower hoist will be described.

The apparatus consists of a contactor panel upon which are mounted the accelerating contactors, overload relay, current-limit relay, and voltage relay; the master controller located at the bottom of the hoist; the emergency controller located at the top of the hoist; the limit switch and rheostats. By means of automatic interlocks on the contactors the connections are regulated between the master controller, limit switch and emergency or upper controller; so that upon turning the master controller to the "on" position the disk brake releases and the motor starts. When the hoist, therefore, reaches its limit in either direction dynamic braking is introduced and the motor stops. When the operator at the top of the hoist desires to stop the hoist he turns the emergency controller to the "off" position, the contactors operate automatically and stop the motor. If the limit switch is now left in an intermediate position the motor will automatically start when the emergency controller is turned to the "on" position. If the limit switch has been turned to the "off" position by the hoist then the motor will not start until the master, or lower, controller is turned to the first controller notch. In case of overload, the overload relay through the interlocks will open the contactors automatically and stop the motor. The hoist cannot be started again until the operator returns the master controller to the "off" position, which permits the plunger of the overload relay to drop. It is necessary to unlock the reversing cylinder of the master controller mechanically in order to use the hoist for lowering. The connections for this operation are so arranged that the accelerating contactors and current-limit relays are inoperative and suitable resistance introduced in parallel with the armature and a large current capacity resistance connected in series with the armature and starting resistance; by reason of which the



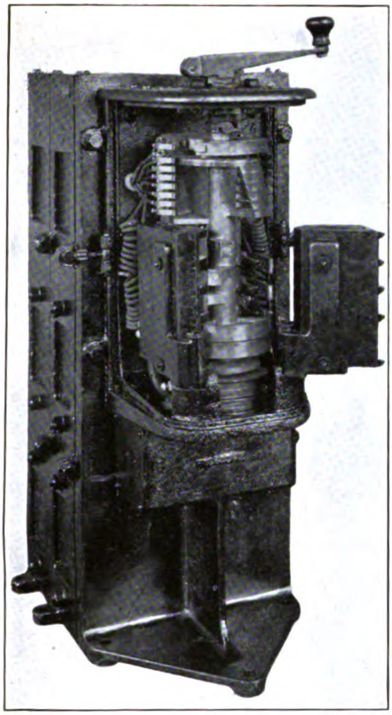
[HORNOR]

FIG. 13—MAINE DISTRIBUTION SWITCHBOARD



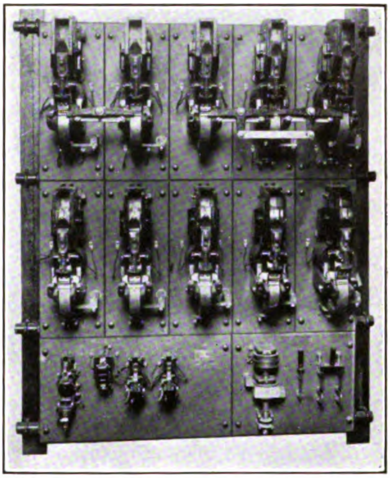
[HORNOR]

FIG. 14—BILGE PUMP MOTOR



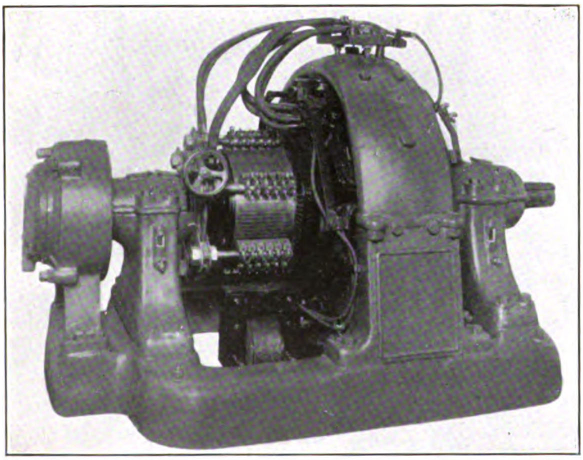
[HORNOR]

FIG. 15—BILGE PUMP MOTOR CONTROLLER



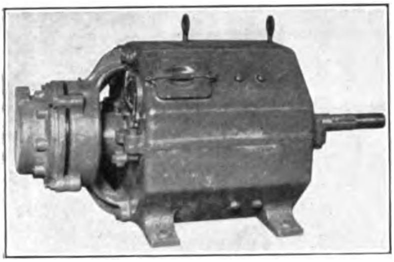
[HORNOR]

FIG. 17—CONTACTOR PANEL FOR STEERING GEAR MOTOR

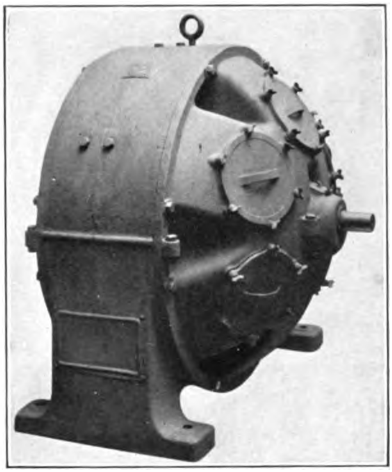


[HORNOR]

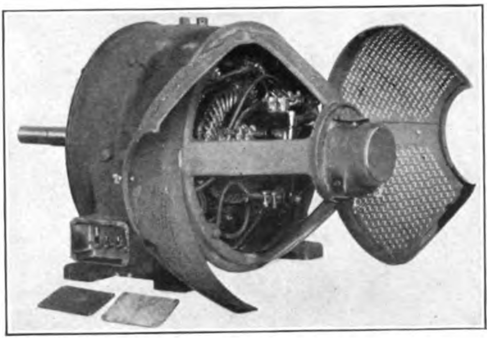
FIG. 16—STEERING GEAR MOTOR



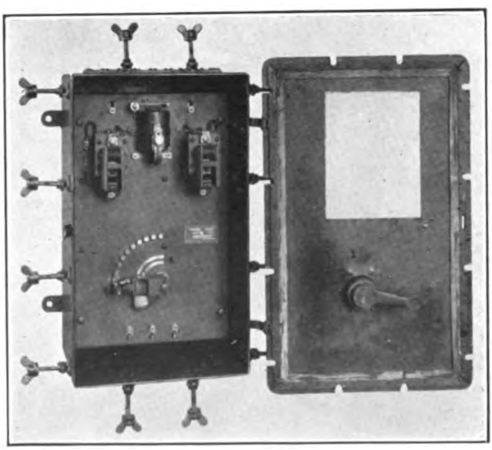
[HORNOR]
FIG. 18—BOAT BOOM MOTOR



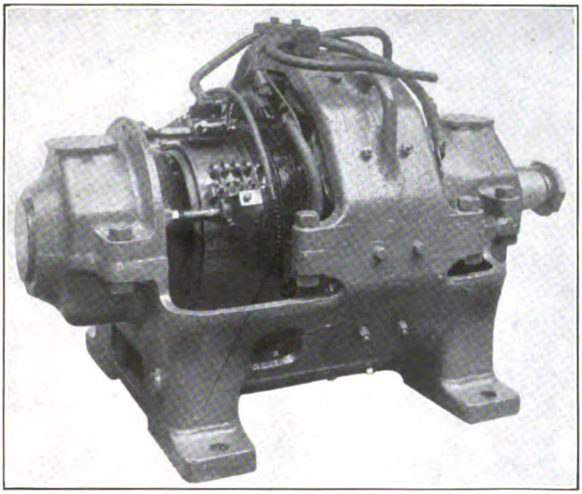
[HORNOR]
FIG. 19—FORCED DRAFT FAN MOTOR



[HORNOR]
FIG. 20—HULL VENTILATION FAN MOTOR

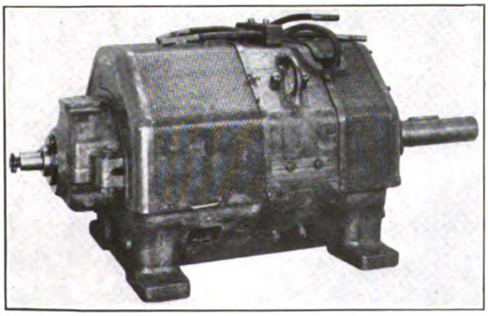


[HORNOR]
FIG. 21—CONTROL PANEL FOR HULL VENTILATION MOTOR



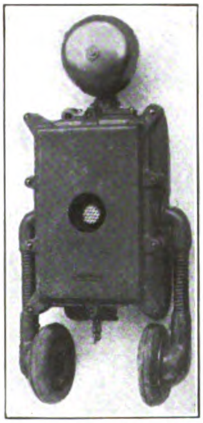
[HORNOR]

FIG. 22—COALING WINCH MOTOR



[HORNOR]

FIG. 23—ANCHOR WINDLASS MOTOR



[HORNOR]

FIG. 26—LOUD SPEAKING TELEPHONE, WATER-TIGHT

hoist will lower slowly. Other functions lowering, are similar to those of hoisting.

Anchor Windlass Equipment

The electrical apparatus acts only as an auxiliary to the steam windlass and is designed to function at half the normal load of the steam gear. The outfit comprises a 100-h.p., 475-rev. per min., compound-wound, commutating-field motor of the open type and is equipped with a disk brake; two water-tight, drum-type, reversing master controllers, one mounted in the windlass room and one mounted on the weather deck; a contactor panel containing the accelerating contactors, a step-back relay, overload relay, a double-pole, single-throw disconnecting switch with field discharge clips, a small single-throw testing switch, and a low voltage relay. The control is semi-automatic, *i. e.*, the first three speeds are controlled by the master controller but beyond that the current-limit relays on the contactors will prevent them from closing until the current in each preceding one has been reduced to a predetermined amount, regardless of the position of the controller cylinder. The setback relay will open the contactors in case the load should be increased beyond that for which the set-back relay has been set, and it will introduce all of the starting rheostat except two sections, thereby reducing the current to about 25 per cent overload on the motor. The overload relay will be set considerably higher than the set-back relay, thus protecting the motor in case of excessive overloads. The overload relay is reset by bringing the controller to the "off" position. The armature and commutating field coils are permanently connected and consequently are reversed together. The low voltage relay prevents the equipment from starting automatically after failure of current, requiring the controller to be brought back to the "off" position whereupon the circuit will be re-established.

Roentgen Ray Outfit

This equipment is arranged for supply from a 220 volt d-c. circuit. The following apparatus of German manufacture is furnished:

An induction coil with adjustable spark gage and three primary windings. The length of spark gap is 16 inches (40 cm.)

Two Gundelach X-ray tubes.

Two Burger-Central X-ray tubes with curved anticathode, air-cooled.

Two Bauer-Delta X-ray tubes with softening adjustment.

One three-part Wehnelt interrupter with one thin and two thick platinum electrodes.

One control switch panel.

The apparatus is located in the operating room adjacent to the sick bay. It is of interest because of the originality of the application.

Moving Picture Machine

Like the X-ray outfit the installation of a cameragraph on a man-of-war is unusual. The outfit represents the very latest design of such machines and is of American manufacture. The apparatus is supplied by a 220-volt circuit and the films are rotated by an adjustable speed, 220-volt, d-c. motor. All the safety attachments required by the underwriters and those automatic devices necessary for smooth performance are provided. The apparatus is portable.

Signaling Systems

The third division of the electrical equipment is classified under the head of Interior Communication Systems, although a few of these are solely for exterior use. They constitute the means for the transmission of intelligence throughout the vessel and are responsible for its behavior when a component part of a military squadron.

The systems comprising this division are given in the following list and a few of the more important and unusual applications will be briefly described.

Call Bells.
Reply Signals for Mechanical Telegraphs.
Fire Alarm.
Electric Clock.
Shaft Revolution and Direction Indicators.
Electric Log Indicator.
Fuel Oil Indicator.
Ammunition Hoist Indicators.
Gun Firing.
Engine Revolution Order Telegraph.
Helm Angle and Steering Telegraph.
Engine Order Telegraph.
Fire Room Telegraph.
Turret Salvo.
Torpedo Defense Salvo.
Anchor Handling.
Coal Bunker Alarm.
Boiler Firing.
Boat Hour Gong.
Day Battle Salvo.
General Alarm.
Cease Firing.
Torpedo Firing.
General Telephone.
Captain's Telephone.
Fire and Engine Room Telephone.

Turret Telephone.
Fire Control Telephone.
12 in. (304.8 mm.) Fire Control Telegraph.
6 in. (152.4 mm.) Fire Control Telegraph.
Turret Danger Zone.
Turret Tell-Tale.
Azimuth.
Course Telegraph.
Gyroscopic Compass.
Pyrometer.
Anemometer.
Electric Whistle.
Wire ess Telegraph.

These systems are supplied with power from two stations on the vessel, the forward interior communication room and the

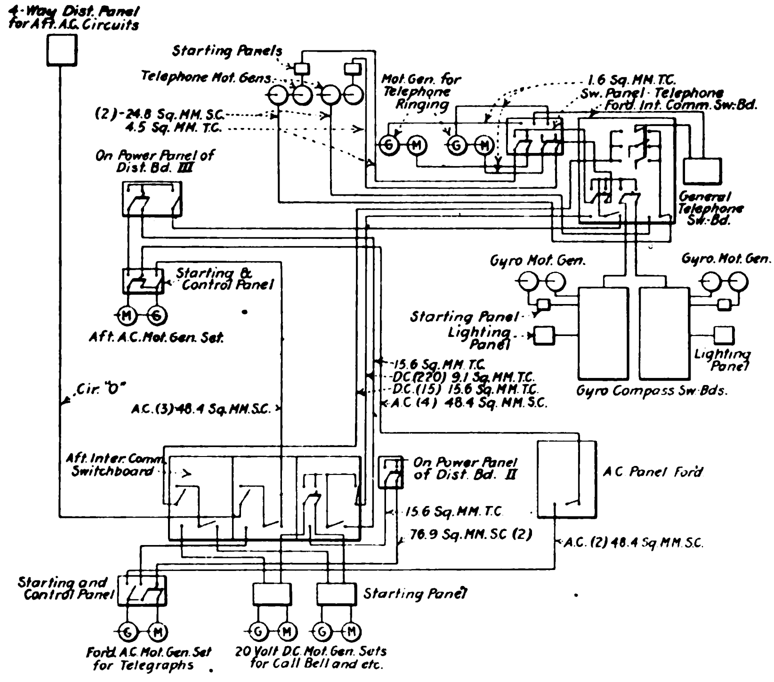


FIG. 24—DIAGRAM OF INTERIOR COMMUNICATION DISTRIBUTION

forward dynamo room. There are two central signaling stations, one forward on the upper platform deck below armor and the other on the gun deck aft. The vessel is further provided with two conning towers, one forward and one aft; two observation towers; and several gun control stations.

A number of these equipments operate on 220 volts direct current, supplied in duplicate from the forward and after main distribution switchboards. However, certain of the telegraph systems require 120 volts alternating current; others, such as

telephone system, clock system, call bell system, require 15 volts direct current; and the fire control telephone system requires 35 volts direct current. These transformations are accomplished by means of small motor-generators, usually supplied in duplicate. The a-c. motor-generators, which are rated at 18 kw. single-phase, 50-cycle, 120 volts, being of rather large size are located one in each dynamo room. The a-c. control panel is located in one of the compartments constituting the forward central station. Supply to this panel is brought directly from the control panel of the after motor-generator set and, *via* the after interior communication control panel, from the forward motor-generator.

The 15-volt d-c. motor-generators are both located in the

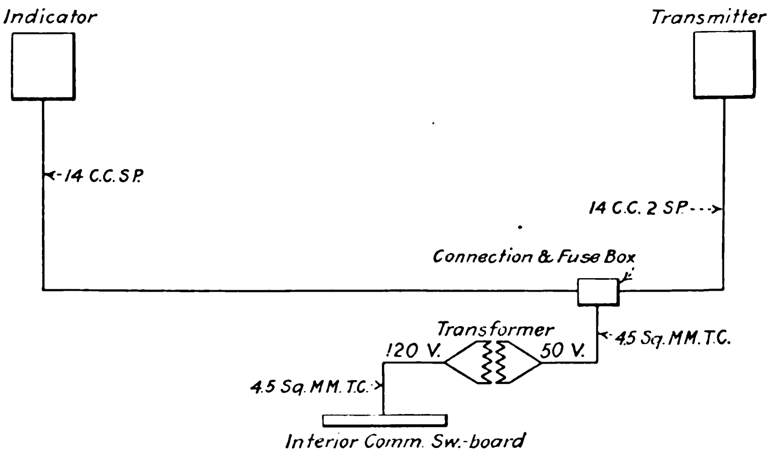


FIG. 25—CABLE SCHEME FOR INTERIOR COMMUNICATION SYSTEM

forward dynamo room directly below the after interior communication control panel, which contains a panel especially for this distribution. Thus the after interior communication switchboard contains three panels; one for the distribution of 220-volt d-c. circuits, one for the 15-volt d-c. circuits, and one for the 120-volt a-c. circuits. The forward interior communication switchboard contains two panels, one distributing 220 volts d-c. and the other 35 volts d-c. This switchboard receives energy from the two 35-volt d-c. motor generators for the fire control telephone system and the two ringing motor-generators for the general telephone system. It also supplies 220-volt d-c. current to the two motor-generators for the gyroscopic compass system. The 220-volt busbars are energized directly

from the after main distribution switchboard, and also from the forward main distribution switchboard *via* the after interior communication switchboard. Every possible precaution has been taken to avert any failure of operation due to lack of supply or interruption of service. It is interesting to note that a diagram of the busbar connections is cut into the face of all switchboards and these grooves filled in with colored paint.

Telegraph Systems

There are about 16 systems, such as Engine Order Telegraph, Course Telegraph, etc., which are operated on the principle of an unbalanced circuit, *i.e.*, when the circuit is undisturbed no current flows. Thus a constant a-c. field, which changes its direction corresponding to the periods of the exciter current, induces currents in the armature coils. The armature of one motor—let us say transmitter—is wound with three interconnected coils and connected by three wires directly to the armature coils of the receiver motor. The power in the armature windings depends upon the rotative position of the armature coils in the field of force. If the armature of the transmitter and receiver have the same position relatively to the field then the induced e.m.f. would be of the same value and the wires between the two armatures would carry no current. If the armature of the transmitter is moved so as to unbalance the armature circuit then current flows in the armature windings, produces a torque, and the armature of the receiver turns to the same position. When this occurs the equalizing currents disappear, and with them the torque.

Any desired number of orders can be arranged for transmission, and any number of receivers connected to the transmitter without increasing the number of connecting wires. Five wires are needed for a simple circuit, two for the field and three for the armatures. For repeating instruments two sets of motors are employed. The transmitter motor is usually larger than the receiver motor, due to the fact that it often operates a number of receivers. Energy is delivered to this apparatus from a 120-volt a-c., single-phase, 50-cycle motor-generator, *via* a step-down transformer, which lowers the potential to 50 volts.

These instruments have a large and varied use as shown in the above list; sending orders from the bridge to the engine room, indicating the position of the rudder direct from the rudder stock to the navigator, giving orders for a change in course of

the vessel, transmitting emergency orders from the bridge or conning tower when the regular steering gear is deranged, ordering small changes in speed when in squadron manoevres, furnishing signals from the gun-firing station to each and every gun, and many other purposes too numerous to record.

Pyrometers

There are six boiler rooms on the vessel from each of which are led three uptakes to the two smoke-stacks. Each uptake is provided with a base metal thermocouple pyrometer. Nine of these eighteen couples indicate at two stations, one in the forward boiler room hatch, and one in the after boiler room hatch. The indicators are of the low-resistance type mounted in special water-tight cases and provided with a nine-point switch for the purpose of reading each uptake temperature. The thermocouples are formed of a nickle alloy wire and capable of constantly measuring a temperature of 1800 deg. fahr. and intermittently up to 2000 deg. fahr. The head of the couple is specially arranged for mechanical protection and water-tightness.

Anemometer

This is an unusual equipment for battleships. The apparatus consists of a transmitter comprising a pivotted rotative vane carrying at one end a fan. The vane in orientation and the fan shaft through a worm gear translate their movements by means of electrical contacts. Thus the velocity and direction of the wind will be recorded. The instrument for the *Moreno* was ordered from France and registers sixteen directions. The direction and velocity of the wind are checked off by the pen on the registering chart in increments of one mile (1.609 km.), every time the wind changes. The maximum record for the chart is 62.13 miles (100 km.) and when the pen reaches this point it automatically returns to zero. The transmitter is located on the top of the forward cage mast and the registering apparatus in the central station. It requires five wires between transmitter and register and operates on approximately four primary cells.

Engine Revolution and Direction Indicator

Each of the three main turbine propelling shafts is equipped with a contact-maker for indicating the number of revolutions, a contact-maker for indicating the direction of the shaft, both

located in the engine room; a synchronizing clock and indicator also located in the engine room near the working platform; and three indicators located in the pilot house, forward conning tower, and central station. Eight wires are required to each indicator, three for the direction tell-tale and five for indicating the speed. Energy for operation is taken from the 15-volt busbars of the after interior communication switchboard. This apparatus is manufactured in Italy and is known as the Molinari speed indicator.

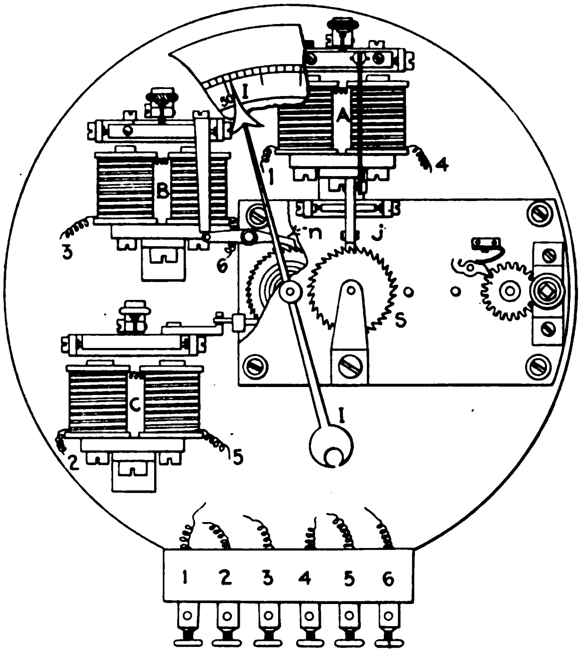


FIG. 29—INTERIOR VIEW OF SPEED AND DIRECTION INDICATOR

The direction contact-maker is a simple make and brake contact operated directly from the shaft through chain and gearing.

The revolution contact-maker consists of a lignum-vitae cylinder carrying three brass sectors made flush with the periphery. It is located near the main shaft and arranged to turn at the same rate of speed. It is provided with two brushes insulated from each other and mounted on spring blocks.

The synchronizing clock controls the make and brake contacts of the revolution contact-maker so that these impulses

may be interpreted by the indicator in measured time. A flat commutator provided with three segments insulated from each other is mounted in the clock and traversed by a metal brush. In this particular installation the "long-make" segment is designed to be maintained for a period of 15 seconds and the two "short-make" segments two seconds each. In this manner the speed during the fifteen seconds previous to reading the indicator is correctly measured.

The indicator consists of a train of clock gears actuated by a spring. Fig. 29 shows an internal view of the mechanism and Fig. 30 represents a plan of the clock works.

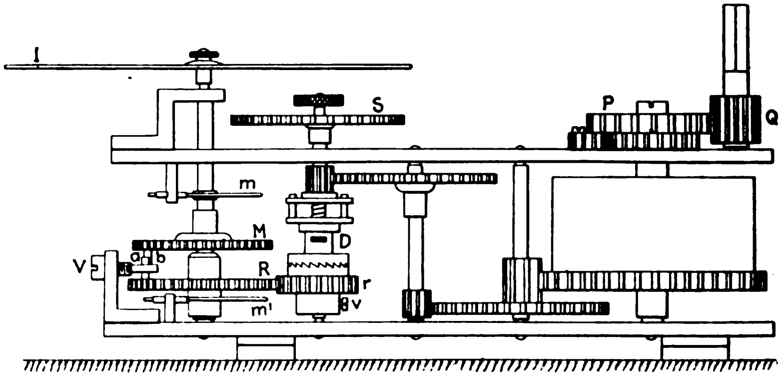
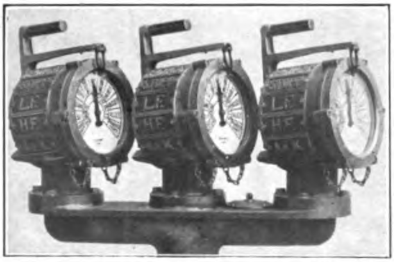


FIG. 30—CLOCKWORK MECHANISM—SPEED AND DIRECTION INDICATOR

WIRELESS TELEGRAPH

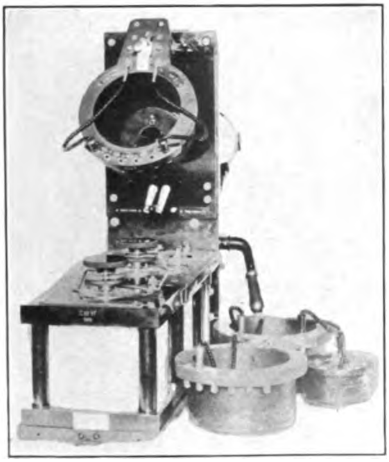
This apparatus is of German manufacture and known as the Telefunken "quench-spark", variometer system. The set is rated as 5 kw. in the antenna with a primary energy of 8 kw. The advantage of the variometer principle is that it permits of a variable range of wave length, which range may be chosen between 600 meters (1968 ft.) and 2000 meters (6560 ft.), depending upon the capacity of the aerial.

The motor-generator set is supplied with a double feeder from both of the main distribution switchboards. This set consists of a 220-volt d-c. motor of 18 h.p. and an a-c. generator rated approximately 8 kw., 500 cycles, 220 volts. The normal speed of the set is 1500 rev. per min. but can be varied for the purpose of altering the spark frequency and thereby the note of the transmitter about 20 per cent in either direction. The pitch of the transmitter note can also be adjusted very exactly by varying the field of the generator.

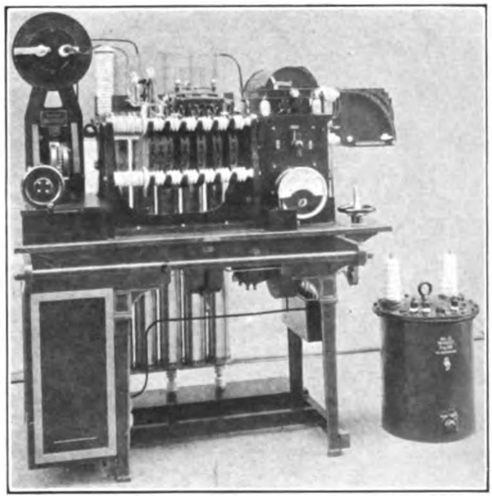


[HORNOR]
FIG. 27—ELECTRIC ENGINE TELEGRAPH TRANSMITTER

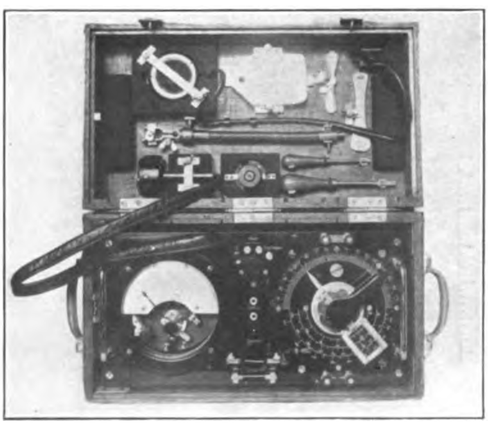
[HORNOR]
FIG. 28—ELECTRIC ENGINE TELEGRAPH RECEIVER



[HORNOR]
FIG. 31—WIRELESS TELEGRAPH RECEIVER



[HORNOR]
FIG. 31A—WIRELESS TELEGRAPH TRANSMITTER



[HORNOR]
FIG. 32—WIRELESS TELEGRAPH WAVE METER

A straight core transformer steps up the 220-volt potential to 8000 volts. A primary choke coil is connected in series with the low-tension winding of the transformer. When the large capacity (5 Leyden jars) is used, the choke coil is used as a quenching coil in parallel with the emergency key. *i.e.*, this coil prevents severe sparking when the emergency key is brought into action. A secondary choke coil is connected in series with the high-tension winding of the transformer. This choke coil affords not only protection against high frequency, but also provides resonance between the transformer and the excitation current.

The closed oscillatory of the transmitter consists of a battery of four or five Leyden jars of a capacity of from 10,000 to 12,000 centimeters each (0.01 to 0.013 micro-farads). Four or five of these jars can be connected by means of a sliding contact as may be required. Next there is provided a 16-part quenched spark gap which is air-cooled (maximum number of gaps to be used 12) and a primary variometer. This latter consists of three fixed and two movable coils which can be connected either in series or parallel by means of a switch. This gives a variable inductance in the ratio of 1 to 16. The variometer scale is graduated so as to enable any wave length between 600 meters (1968 ft.) and 2000 meters (6560 ft.) to be adjusted in a moment.

The antenna will be of the L type, slanting from the foremast to the mainmast. The direct distance is 196 ft. (59.8 m.) and the hypotenuse 206 ft. (62.8 m.). The antenna capacity has been fixed to absorb an oscillatory energy of 5 kw. without loss, providing for the above stated wave lengths. In this circuit is the antenna variometer which consists of six fixed and five movable coils arranged in two groups. By means of the scale and the corresponding curves, waves up to 1450 meters (4756 ft.) can be adjusted. For waves above this a lengthening coil is connected in series with the variometer which increases the wave range to 2000 meters (6560 ft.).

For receiving purposes a crysta detector is used It is claimed that this has the property of converting the high-frequency currents flowing through it into unidirectional currents. Therefore, it operates without any auxiliary e.m.f. and the receiving apparatus does not contain a local battery. It is also claimed that a very high degree of sensitiveness is shown when receiving at long distances. By its use the connect'ons are also very much simplified. Underneath the var'able receiving transformer

is a two-pole change-over switch marked "long waves" and "short waves." When the switch is on the position "short waves," the connections are as follows: Antenna lengthening coil, variable condenser, earth or counterpoise. When the switch is on the position "long waves," the lengthening coil and variable condenser are connected in parallel to form a closed oscillatory circuit. The antenna now is connected to one pole of the condenser and the earth or counterpoise to the other.

With both methods of connection, the energy is transferred from the low-tension transformer coil which is in series with the antenna into the high-tension transformer coil. The latter forms, with the detector an aperiodic circuit. This requires only one circuit to be tuned viz.—for "short waves" the antenna circuit and for "long waves" the closed oscillatory circuit. Means are also provided for increasing the capacity of the receiver through an intermediate circuit whereby disturbances from other stations and atmospheric discharges may be avoided.

The design of this apparatus is such as to provide every means for the protection of the apparatus and operator from high tension. Behind the vertical frame of the receiver is a high-tension terminal and the high-tension switch, to which the leads from the antenna and the transmitter are connected. By this means the antenna is connected to the receiver and the transmitting circuit automatically interrupted.

This equipment had a guaranteed range of 1000 kilometers (621.3 miles) by day and 2100 kilometers (1304.7 miles) by night. That these guarantees will be exceeded in practise is seen in the report of trials on the sister ship *Rivadavia*, where communication was held between Boston and Colon, a distance of approximately 2000 miles (3218 kilometers).

Gyroscopic Compass

This apparatus is of German manufacture and is named, after its designer, the Anschütz gyro-compass. The design is based upon scientific principles laid down by the famous French philosopher Foucault. He arrived at the conclusion "that any gyro with only two degrees of freedom, *i.e.*, free to move in two planes only, will at any place on the earth's surface, other than the two poles, tend to set itself with its axis of rotation parallel to the axis of the earth itself, by reason of the relative rotations of the two bodies."

The practical value of this mechanism depends upon two

essential points; the oscillations must be effectively "damped" and the suspension must be as nearly frictionless as possible. If the gyro be considerably deflected from the meridian line it will swing for a very long time and in this condition many new forces are brought into play. In this compass the movement of air set up by the gyro-motor not only provides ventilation for the motor but also enables "damping" of the oscillations. A small rectangular outlet for the air is cut in the gyro case, the space in the base of the binnacle is designed so that the air blast will be free from air currents in the casing, and thus the forces tending to tilt the gyro from the horizontal are opposed.

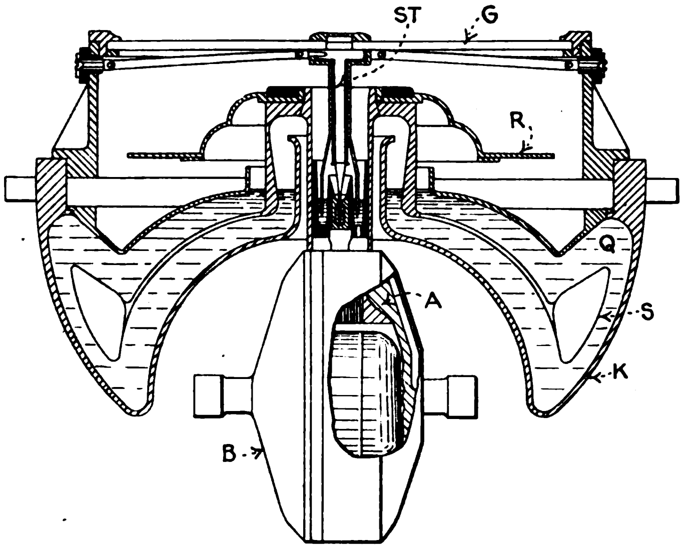


FIG. 33—SECTIONAL VIEW OF GYROSCOPIC COMPASS

As will be seen in Fig. 33, the complete gyro with motor casing, etc., is suspended by means of a circular, hollow, steel float in a bath of mercury. The mercury bowl is supported on gimbals in the same manner as any ordinary magnetic compass. The compass card is directly attached to the float and gyro and the gyro axle is directly under the north and south points of the car. The gyro always points due north and south. "In order to keep the whole floating system central a steel stem is fixed centrally in the top glass and the lower end of the stem dips into a small mercury cup carried on the top of the float. A similar connection is effected by a steel tube mounted concentrically

with the stem and a second mercury cup. These two sets of connections are electrically insulated from one another and from the general metal portions of the apparatus. These two connections carry two phases of a three-phase current to the motor of the gyro; the third phase reaches the motor through the mercury bowl, mercury and float. The motor of the gyro consists of a very small three-phase motor, the stator of which carries the windings so that all the connections can be rigidly made. The rotor is rigidly fixed into the inside of the gyro flywheel itself." Special nickel steel is used throughout and the axle is supported on ball bearings of specially hard steel.

The master compass receives its energy from duplicate motor-generators. The motor-generator transforms the 220-volt direct-current to three-phase alternating-current at 120 volt and 333 cycles. The alternator has 16 poles and runs at a normal speed of 2500 rev. per min. Therefore the gyro motor, which has two poles, runs at approximately 20,000 rev. per min. A control panel is provided upon which are mounted meters, switches, fuses, etc.

The master compass is arranged so that the mercury bowl may turn without any work being thrown on the gyro. The design is such that the mercury bowl always "follows" the movements of the gyro. This is only apparent, as it is the ship and binnacle that move. When the ship turns, a corresponding movement is imparted to the mercury bowl. The compass card of the floating system carries a small contact ball which is in contact with one phase of the three-phase supply. Attached to the mercury bowl but insulated from it are two semi-circular contact bands. Any movement of the ship will bring the contact ball of the floating system into contact with these semi-circular bands. These contacts control a two-phase reversible motor mounted on the gimbal rings which when contact is made rotates the mercury bowl until the contact is broken and the circuit to reversible motor is open. This motor, as just described, receives its two-phase current from two of the three phases driving the gyro-motor.

The transmission of these motions to the receiving compasses is accomplished by means of a commutator mounted on the axle of the reversible motor. This commutator is constructed half of glass and half silver. Four sets of brushes are arranged around the commutator at a distance of 120 deg. Connections are made from each of these points to each receiver. The motor

of the receiver has a stator similar to that of a star-connected three-phase motor. The star point of the stator is connected by a brush to the shuttle armature. This synchronizing arrangement is claimed to repeat these movements with an accuracy of one-sixth of one complete revolution. The receiver motor is operated by direct current through a special resistance which acts like a potentiometer resistance and which branches the direct current at 140 volts. The supply of direct current is controlled by the same switch which controls the alternating current so that any failure of the supply will not throw the receiver out of synchronism. The receiver motors are geared to their outer compass card in the same ratio as the reversible motor of the master compass is geared to the mercury bowl.

General points of interest regarding this device may be summarized as follows:

Peripheral speed of the gyro is 500 ft. (152.5 meters) per second or 340 miles (547.06 km.) per hour.

The air friction is so great that it absorbs 95 per cent of the power of the gyro-motor.

The directive force on the gyro-compass is approximately 15 times as great as a magnetic liquid compass, free from all disturbances.

The gyro-compass, unlike the magneti ccompass, points to the true north pole of the earth.

Directive force diminishes as the poles of the earth are approached, because of the higher latitude. Therefore the actual distance moved by the gyro (in space) in a given time is smaller. No directive force exists at the poles. Every line there is a meridian.

The angular momentum about the axle of the gyro is always 100,000 times, and sometimes 1,000,000 times, as great as the component of the angular momentum due to precession.

The following numerical data obtained from an actual instrument may be of interest.

Righting coefficient at the equator	20,190 dyn. cm.
Moment of inertia	404×10^7 g. cm^2
Period of damped oscillation	4,110 seconds
Period of undamped oscillation	3,680 seconds

CONCLUSION

This equipment is the largest and most costly ever installed in this country, comprising 3000 electric lights, 4000 rated h.p.

and approximately 76 miles (122.3 km.) of cable. It is a noteworthy engineering achievement in that it was a departure from American practise in the use of 230 volts; in the employment of lead-covered, steel-armored, conductors; in the application of 220-volt tungsten lamps; in the use of electricity for the purpose of steering the vessel, operating the anchor, and the bilge pumps; and many more advances in the application of electrical power. The result has been fruitful to the American manufacturer in that he is now prepared to furnish standard 230-volt apparatus designed for use on shipboard. This equipment also stands as a practical solution of the many problems involved and as a working comparison with previous equipments.

To be presented at the 300th meeting of the American Institute of Electrical Engineers, Philadelphia, Pa., October 12, 1914. under the auspices of the Committee on Use of Electricity in Marine Work.

SUBMARINE SIGNALING

THE PROTECTION OF SHIPPING BY A WALL OF SOUND AND OTHER USES OF THE SUBMARINE TELEGRAPH OSCILLATOR

BY R. F. BLAKE

ABSTRACT OF PAPER

Submarine signaling has been greatly advanced by the introduction of a powerful sound transmitter and receiver called the "Fessenden telegraph oscillator." By means of this, telegraph messages can be sent and received through the water by moving ships and for short distances speech can be transmitted, icebergs can be located, and soundings taken instantaneously.

The apparatus consists of an oscillating electric motor-generator which has a strong electromagnet surrounding a central core on which is an alternating-current winding. Between the core and the magnet is a copper tube which acts as a closed secondary to the core winding. This copper tube is attached to a large diaphragm. When the alternating current passes through the core winding it induces a current in the copper tube, which, being free to move, vibrates back and forth, thus setting the diaphragm in vibration.

This apparatus is installed in a ship so that the face of the diaphragm is in contact with the water and its vibrations set up sound waves in the water. Signals have been sent a distance of 31 miles.

The oscillator can also be used as a receiver. Sound waves striking against the diaphragm cause the copper tube to vibrate, thereby generating a current in itself which is induced in the core winding. A telephone receiver in the armature circuit enables the observer to hear the sound.

COMPARED with other forms of transportation, the amount of energy necessary to transport water-borne freight is very small and its cost would be cheap indeed if it were not for the dangers of the sea. We have fogs and rocky coasts, shoals and icebergs, currents and storms to guard against, and these add immensely to the expense. Of this we have had a very recent instance, for, as the result of the loss of the *Titanic*, vessels carrying passengers are now constructed with a complete double bottom extending above the water line, in other words, instead of a single ship, we must now have two complete ships, one en-

tirely enclosed by the other. And the loss of the *Empress of Ireland* indicates that even this may not be adequate.

Bit by bit the dangers which beset the early navigators have been overcome. The chart told him the best course to take from one point to another. The mariner's compass enabled him to maintain his course when the stars were blotted out by clouds. With sextant and chronometer he located his position, with log and soundings he guarded himself when a sight could not be obtained. More recently wireless telegraphy has enabled him to call assistance in time of danger. But with all this, many dangers remain. The more important of these are due to fog.

The North Sea, the English Channel and the Grand Banks, the New England Coast, the Western Coast of the United States, British Columbia and Alaska, and other points are all of them subject to fogs, sometimes lasting for weeks at a time, and it is therefor not surprising that thousands of lives are each year still lost at sea.

And there is not only loss of life; the pecuniary loss is also very great. It is no unusual occurrence for a score of steamers to be tied up at one time, unable to enter harbor on account of fog or of the combination of fog and rough weather.

In such a case, the loss to the steamship companies in interest and depreciation on ships and cargoes and in wages may easily amount to more than fifty thousand dollars per day, and this loss occurs not once but frequently during a year, and on many routes.

In addition to this, the danger of collision in fog adds very considerably to the cost of insurance, and some of our worst disasters have occurred in this way.

Aside from those dangers peculiar to fog, there remains a number of others. A continuance of cloudy weather or abnormal ocean currents or both, may throw the navigator out of his reckoning and place him on a rocky shore a score of miles away from the safe route he assumes himself to be following.

Icebergs still remain a menace in spite of all the efforts which have been made to guard against them. From time to time, statements have been made that apparatus has been devised which is capable of locating their presence, but in every instance in which such apparatus has been tested it has proved a failure.

The history of systematic marine protection by means of lighthouses and beacons does not go back very far. It is true that there were a few lighthouses such as the Pharos of Alexandria

centuries ago, but even in quite recent years a European Government received a petition for compensation from the inhabitants of a sea coast district on the ground that the erection of a lighthouse had deprived them of one of their principal sources of income, to wit, luring vessels on nearby shoals by means of false lights.

The systematic employment of sound signals for marine protection is of still more recent date and has never been carried out fully, in spite of the fact that many of our greatest scientists, for example Tyndall and Rayleigh, have devoted special attention to this matter.

One reason for this is that sound signals produced in air are very erratic in their range and intensity, so much so as to be on many occasions absolutely misleading. This is due to the fact that when a fog-horn is blown, the sound may be carried by the wind or may be reflected or refracted by layers of air of different densities, with the result that the sound may be audible many miles away while there may be a zone of complete silence extending from a few hundred yards in front of the signal to a distance of four or five miles.

As this phenomenon is by no means infrequent, the result has been to discredit more or less this type of signal, and it will be evident that the knowledge that a siren had been installed at a certain dangerous point might prove a source of danger instead of a protection.

As already stated many eminent men have worked upon this problem, but it was not until Arthur J. Mundy, of Boston, suggested the use of water instead of air as the medium for transmitting signals and proved its value by practical demonstration that any great advance was made. Water has many advantages over air for this purpose.

1. In the first place it is free from the dangerous zones of silence which occur when the signals are produced in air.

2. In the second place, the absorption of the sound is much less in water and consequently the signal is not only absolutely reliable but is transmitted to a distance many times greater than when it is transmitted through air.

3. The sound is not carried away by the wind in stormy weather, as is the case with the siren.

4. It is not affected by atmospheric disturbances, as is the case of wireless.

5. It permits of the accurate determination of the direction

from which the sound is proceeding, which is not the case with either the air siren or wireless telegraphy.

Some recent instances where ships have signaled by wireless that they were in distress but have had to remain without assistance for many hours, and in one instance for more than a day, because their location could not be determined by the vessels coming to their aid, will be familiar to every one.

All these advantages indicated clearly years ago the advisability of developing apparatus for signaling by means of sound waves transmitted through the water itself.

But it is one thing to conceive the idea, and another thing to develop a practical system, and it may be of interest to know that up to the present time the sum of a million dollars has been invested in developing submarine signaling, so far without monetary return.

The first method which was employed for producing the sound was through the striking of a bell and the method of receipt of the signals was by means of a microphone attached to the skin of the ship. Neither the original bell nor the original microphone attachment was satisfactory.

It would be impossible in the space permitted to discuss even briefly the innumerable experiments made with different sizes of bell, with different materials for the bell, with different methods of producing the blow, the precautions taken to eliminate electrolytic action, with different types of microphone, with different methods of mounting the microphone on the side of the ship, with the experiments made to minimize water and other noises. It will be sufficient to say that finally the work of Mundy, Wood, Fay, Williams and others resulted in a completely practical system.

The submarine bell in use on the lightships is actuated by compressed air stored in a reservoir. The actuating wheel has projections mounted on it so that when the wheel revolves a number of strokes follow each other, the different intervals being peculiar to the different signal stations so that the captain of a ship by counting the strokes of the bell can determine what lightship is producing the sound.

In order to receive the sound, it has been found absolutely necessary to suspend the microphone in a tank of water, for this is the only method of cutting out the water noises and the noises due to machinery, etc., on board the ship, which otherwise drown out the sound of the bell.

One of these small water tanks, containing a microphone of a special type, is attached to each side of the bow inside of the ship. From each tank wires are run to a device which is called the indicator box, so arranged that by throwing the handle to one side, the starboard microphone is connected to the telephone, and by throwing the handle to the other side, the port microphone is connected.

It will be obvious that once the bell is picked up, the captain has only to turn his vessel until the sound is heard with equal intensity on each side, to know that his ship is then pointing in the direction from which the sound is coming, and in this way he can take compass bearings of the lightship on which the bell is situated.

The importance of this method will be at once perceived. No matter how stormy or how foggy the weather may be, it enables the captain of a ship, on making land, to obtain at once the compass bearings of the nearest lightship or lighthouse fitted with a bell.

How many vessels and how many lives this device has saved even in the few years during which it has been in use, it would be impossible to tell. Less sensational than the wireless telegraph, it may be questioned whether its actual practical utility to the merchant marine has not been greater.

Compressed air, or an electromagnetic mechanism, may swing the hammer, or the bell may be operated by the waves themselves. A type much used is a bell buoy which may be anchored off a shoal, and will give submarine warning day and night without further attention. A large vane extends from one side of the mechanism. As the buoy swings up and down in the water, the vane by means of a ratchet compresses a spring which automatically releases and operates the bell hammer.

It will be evident that, even if no further development had been made, the system would be and is a complete and practical one. Its universal adoption would greatly minimize if not entirely prevent disasters due to errors of ship position.

But with the very success of this system, it became evident to those in charge of its development that still further advances might be conceived as possible, especially in three directions.

1. Suppose the sound-producing apparatus could be so constructed as to be operated from moving ships by a telegraph key. If this were achieved, it would be possible for one ship to signal to another in fog, to communicate its position, its

direction and its speed, and eliminate all dangers of collision. It would also be possible to signal between submarines or between battleships and submarines, and to communicate between battleships in action without interference from the enemy and though all masts were shot away.

2. Suppose the range of the sound-producing apparatus could be extended so as to cover a radius of 25 or 50 miles. Then it would be within our power so to encircle the coast of every nation, with what has been felicitously termed "a wall of sound," that no vessel under whatsoever circumstances of loss of reckoning, of variable currents, of fogs, and storms could approach the coast without being warned of that fact and notified of its exact position on that coast and of the direction of the nearest lightship.

3. If the sound-producing apparatus could be constructed so as to be actuated by telephonic currents, it would be possible to transmit speech through the water.

It will be of interest to consider some of the difficulties which had to be overcome before the desired results could be obtained.

The most serious of these obstacles was the fact that water is almost incompressible.

Now since sound is a compressional wave in the medium through which it is transmitted, it is evident that any apparatus which is to transmit sound through water must be capable of exerting very great force. In the bell, this is accomplished by the hammer blow of the clapper, and any electric or other apparatus which is to be used for submarine signaling must have a force comparable with that produced by the impact of a hammer on an anvil.

A second and very grave difficulty arises from the fact that if the water is to be compressed, some material object must be set in motion to compress it, and that object, which must have sufficient mechanical strength to stand the stress, and must therefore be of considerable size, must start from rest, reach its highest velocity, and come to rest in one-thousandth part of a second, if a musical note having a pitch of five hundred per second is to be produced. The forces of acceleration thus necessitated are very large.

A third difficulty arises from the fact that in order to telegraph at a speed of twenty words per minute the time allowable for a single dot is very small. As the average word consists of five letters, and the average letter has a length equivalent

to seven dots, an apparatus capable of telegraphing at the rate of twenty words per minute must be capable of making seven hundred dots per minute, or a single dot in something less than one-ten h of a second.

If the signal is to have individual quality, so as to be readily distinguishable from other noises, and so as to be separable by resonance from other notes, each dot must consist of at least ten impulses.

Thus we arrive at the conclusion that whatever device is used, it must be capable of producing at least 100 compressional waves in a single second, in order to telegraph satisfactorily at the rate of twenty words per minute.

If this same apparatus is to transmit speech through the water, it must be still more rapid in its action and must be capable of producing several thousand compressional waves per second.

The above were the three main difficulties in the way. Of course there were many others, for example, the apparatus must not weigh too much; it must not be affected by water or change of temperature; it must be simple in construction; it must be easily applied to the ship; positive in its action; must not require adjustment after being once set up and must be able to stand all kinds of ill-treatment at the hands of unskilled operators. It will be unnecessary to go over the ground taken by the development, and we will therefore proceed at once to describe the apparatus as finally developed by Professor R. A. Fessenden.

The device used is termed an oscillator and its construction is shown in cross-section in the drawing, Fig. 1.

In the drawing, the iron of the magnetic circuit and the copper tube are shaded. The magnetizing coil is cross hatched. The moving part is the copper tube *A*. This lies in the air gap of a magnetic field formed by a ring magnet *B*, built up in two parts, as shown in longitudinal section in Fig. 2.

The ring magnet is energized by the coil *C*, and produces an intense magnetic flux which flows from one pole of the ring magnet across the air gap containing the upper part of the copper tube, thence through the central stationary armature *D*, thence across the other air gap to the lower pole face of the ring magnet and thence through the yoke of the ring magnet back to the upper pole face.

This field is very much stronger than that in the ordinary dynamo, there being more than 15,000 lines for each square centimeter of cross-section.

Around the armature is wound a fixed winding, which we will call the armature winding, and which is reversed in direction so that one half of the winding is clockwise and the other counter clockwise.

When an alternating current is passed through this armature winding, it induces another alternating current in the copper tube.

Only by this construction has it been found possible to obtain the enormous force and rapidity necessary to compress the water

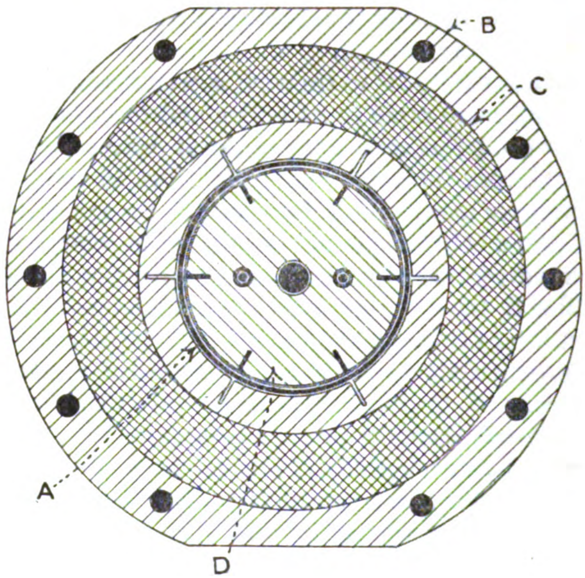


FIG. 1

and to overcome the inertia of the moving parts of the mechanism.

In order to apply this force to the work of compression, the copper tube is attached to solid disks of steel, which in turn are attached to a steel diaphragm one inch thick which may be made part of the side of the ship. In practise the tube is provided with lugs, and is held between two disks drawn together on the tube by a one-inch vanadium-steel rod and a right- and left-handed screw thread.

Telegraphing is accomplished by means of an ordinary telegraph key placed in the main armature circuit.

Although an ordinary telegraph key is used, there is no

sparking at the contacts. This may surprise electrical engineers familiar with the sluggish action and vicious arcing commonly found associated with the operation of electromagnetic apparatus of this size and power, more especially in view of the fact that a very high frequency is used, five hundred per second, and that there is no laminated iron used in the construction of the apparatus.

The secret of this lies in the fact that the armature has substantially no self-induction, and no eddy currents are generated in the apparatus. This is because the copper tube forms, as will be seen, the short-circuiting secondary of a transformer, of which the armature winding is the primary.

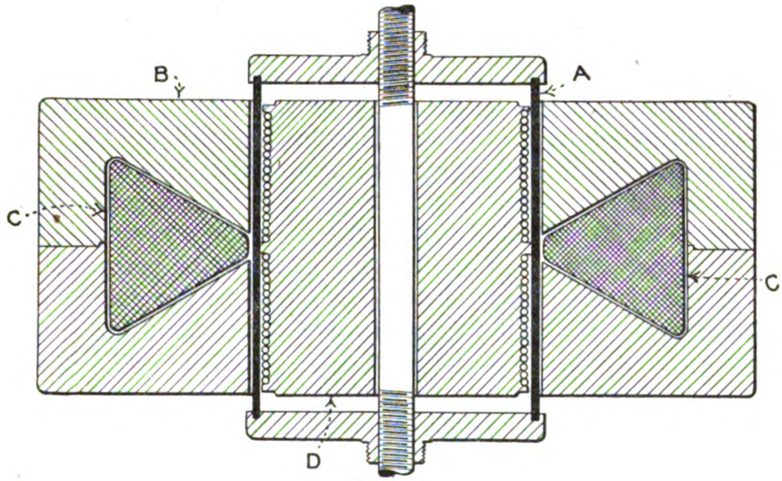


FIG. 2

This eliminates the self-induction of the armature winding. In addition the upper and lower portions of the winding are wound in opposite directions, and therefore there is no mutual induction between the field coil circuit and the armature circuit. With this construction, the amount of magnetic leakage in the armature circuit is very small, only a trifle more than if the armature core were of wood, and as there is no alternating magnetic flux in the iron, there are no eddy currents.

As regards the capacity in kilowatts of this apparatus, it is large. The armature, being wound in grooves in the armature core, so as to withstand the mechanical forces acting upon it, is well cooled.

The copper tube has no insulation to be affected, and on account of its large cooling surface and high permissible temperature of operation, can carry very high currents without injury.

When the oscillator is placed on a vessel or hung overboard from a lightship, a large water-tight diaphragm is attached to the oscillator. This particular type of oscillator was first tested by suspending it in twelve feet of water at the Boston lightship and the signals were heard plainly with a microphone lowered overboard from a tug at Peaked Hill Bar Buoy, thirty-one miles away. Since that time tests have been made with oscillators installed in the fore peak tank of the *Devereux,* a collier of the Metropolitan Coal Company, and also with an oscillator mounted on a diaphragm made part of the hull of the vessel. The signals have been heard upwards of twenty miles from the *Devereux* running at her regular speed of eight knots. Full power has not been employed on any of the tests, and it is more than probable that much longer distances can be obtained in the future.

In addition to the tests already described the oscillator has been temporarily installed on submarine boats, and proved itself of immense value and demonstrated that a flotilla of submarines equipped with oscillators will be able to make a combined attack on an enemy, only one needing to show its periscope in order to direct the others, or all of them can be directed by the mother ship. It therefore makes possible a whole field of submarine manoeuvres heretofore out of the question; and perhaps most important, it removes the principal danger these boats have had to face, the risk of being run into.

So much for the apparatus when in use as a sound generator. The signals produced by the oscillator can of course be received by water-immersed microphones of the usual type, but one would perhaps not anticipate the possibility of using the oscillator as a receiver, in view of the fact that the diaphragm is of solid steel, and weighs, with the copper tube and its attachments, considerably over 100 pounds; but the oscillator, like the ordinary electric motor, is also capable of acting as a generator, and on account of its high efficiency as a motor, is a very efficient one.

The same oscillator is therefore used for sending and for receiving, a switch being thrown in one direction when it is desired to telegraph under water, and thrown the other way when it is desired to listen in.

In addition to telegraphing and receiving messages, the

oscillator can also be used for telephoning under water. Sentences have been transmitted at 800 yards and conversation at more than 400 yards, and this was accomplished with the use of an ordinary telephone transmitter and 6 dry cells.

It seems evident, therefore, that with more power much greater distances can be reached. Long distances are not, however necessary, as even with a distance of one mile it will be readily understood that this method of under-water telephoning will be of great use as a means of communicating between submarines while submerged, and between ships in fog, as the captains of the vessels can talk directly to each other, instead of transmitting and receiving through a telegraph operator.

Some other uses to which the oscillator may be put may be mentioned briefly.

One which will at once suggest itself is the steering of torpedoes by sound under water. The idea of so operating torpedoes is not a new one, and has occurred to a number of inventors, but until the present time no method of accomplishing it has been developed. With this new source of sound, however, the method should be practicable.

Another use is as a means for obtaining soundings. If we take a commutator wheel, with one live segment and two brushes, one connected to the alternating-current generator and the other to the telephone receiver, it will be evident that when the commutator segment makes contact with the brush connected to the generator, a sound will be produced by the oscillator. When the live contact passes away from the brush, the sound will cease. This sound wave will travel outward and on reaching the bottom will be reflected and travel back again to the ship. Meantime, no sound will be heard in the telephone receiver, but if the brush connected to the telephone receiver be shifted in the direction of rotation of the commutator until it makes contact with the live segment of the commutator, at precisely the instant at which the reflected sound wave has come back and impinged on the oscillator diaphragm then a sound will be heard. Since sound travels in water at a velocity of approximately 4000 feet per second, if the distance be 100 feet, the time taken by the sound in traveling from ship to bottom and from bottom to ship will be approximately one-twentieth of a second.

In April, 1914, some tests were made on the U. S. revenue cutter *Miami* to see whether soundings could be taken in the

manner above indicated. As the commutator had not been completed a temporary apparatus with a stop watch was used. The echo from the bottom was plainly heard not only on the oscillator, but in the wardroom and in the hold of the ship without any instruments whatever. The elapsed time corresponded to the depth shown on the chart and the proposed method was proved to be feasible.

The chief object of the tests on the *Miami* was, however, to determine whether a reflection from icebergs could be obtained, and this was proved beyond question. The apparatus used was the same as for taking soundings.

A signal was sent on the oscillator, the echo from the bottom heard, and then the echo from the iceberg came in. To make sure that the second echo was not also from the bottom, the distance from the *Miami* to the iceberg was varied from about 100 yards to 2½ miles. The elapsed time between the signal and the echo from bottom remained the same, but the elapsed time of echo from the iceberg varied with the distance and corresponded very closely to the position of the iceberg determined by the range finder. Moreover it was found that it made no difference whether the face of the iceberg was normal to the path of the sound or not, thus showing that the echo was due not to specular reflection but to diffraction fringes.

When the *Miami* had gone 2½ miles from the iceberg a heavy storm made it necessary to postpone further tests, and continued rough weather made further tests impossible, as the oscillator was not permanently installed but had to be lowered overboard. The echoes at 2½ miles were, however, loud, and there can be no doubt that they would have been heard at greater distances. (See appendix).

To sum up: The oscillator represents an important step forward in the science of navigation. It makes it possible to surround the coasts with a wall of sound so that no ship can get into dangerous waters without warning, to make collisions between ships possible only through negligence. Although no sufficient tests have been made to warrant the statement that icebergs can be detected under all circumstances or that soundings can be taken at full speed, what evidence there is points that way. For naval purposes it provides an auxiliary means of short distance signaling that is available at all times and that cannot be shot away, and it widens the possibilities of submarine boats to an extent we cannot yet fully grasp.

Report of Captain J. H. Quinan of the U. S. R. C. *Miami* on the Echo Fringe Method of Detecting Icebergs and Taking Continuous Soundings.*

We stopped near the largest berg and by range finder and sextant computed it to be 450 feet long and 130 feet high. Although we had gotten within 150 yards of the perpendicular face of this berg and obtained no echo from the steam whistle, Professor Fessenden and Mr. Blake, representatives of the Submarine Signal Company, obtained satisfactory results with the submarine electric oscillator placed 10 feet below surface, getting distinct echoes from the berg at various distances, from one-half mile to two and one-half miles. These echoes were not only heard through the receivers of the oscillator in the wireless room, but were plainly heard by the officers in the wardroom and engine room storeroom below the water line. Sound is said to travel at the rate of 4400 feet per second under water. The distance of the ship, as shown by the echoes with stop watch, corresponded with the distance of the ship as determined by range finder. On account of the great velocity of sound through water, it was our intention to try the oscillator at a greater distance for even better results, but a thick snowstorm drove us into shelter on the Banks again.

* * * *

On the morning of April 27, anchored in 31 fathoms of water with 75 fathoms of chain in order to make current observations. . . .Professor Fessenden also took advantage of the smooth sea to further experiment with his oscillator in determining by echo the depth of water; the result giving 36 fathoms, which seemed to me very close.

*From the *Hydrographic Office Bulletin* of May 13, 1914.

To be presented at the 300th meeting of the American Institute of Electrical Engineers, Philadelphia, Pa., Oct. 12, 1914.

(Subject to final revision for the Transactions.)

ELECTRICAL FEATURES OF THE U. S. RECLAMATION SERVICE

BY F. H. NEWELL

ABSTRACT OF PAPER

The operations of the U. S. Reclamation Service are of interest to electrical engineers not only in some of the novel developments and applications of power but also as illustrating the efforts of the federal government in the construction of works of general public utility.

One of the most interesting features is the question of cost of government work, much of which in this case is executed under pioneer conditions. These costs are carefully recorded and include all of the overhead or general expenses. These costs show that during 1913, for the various plants there was a range from 0.68 cent per kelvin or kw-hr. up to 2.873 cents. The power not needed for construction purposes or for operating irrigation works is being sold at rates of 1.5 cents per kw-hr. being for excess power as low as 0.5 cent up to 2 cents or over. For heating the rate charged per month June 1 to September 1 per device per 1,000 watts is $1.50.

The experience obtained is illustrating the fact that it is practicable for the government to build and operate plants of this kind and sell the power at cost, in connection with other enterprises and with general satisfaction to the consumer. The power plants will be paid for without profit or interest and the operations transferred as soon as practicable to the communities benefited by them.

THE electrical engineer as a professional man finds much of interest in the works executed by the United States Reclamation Service and in the plans under consideration for further enterprises. Electrical development and transmission enter largely, not only into the construction, but also into the operation of the works for the irrigation of arid lands, which are being built under the terms of the act of June 17, 1902. This act sets aside the proceeds from the disposal of public lands in the western arid and semi-arid states, for the purpose of survey, construction, operation, and maintenance of works for the storage and distribution of water for irrigation and reclamation of arid lands.

Aside from his purely professional interest, the electrical engineer, as a citizen, is concerned in all of these matters which have to do with the upbuilding of the United States, the utiliza-

tion of its natural resources, and the increase of the prosperity and happiness of the commonwealth. Both of these phases, that of interest to the professional man and to the citizen, are briefly discussed in the following paragraphs, the attempt being made to describe in a concise way the works which have been or are being built and to give the relationship of these to the larger economic or political problems of the country.

Object. The main purpose in the development of electric energy by the Reclamation Service is the production of cheap power for raising underground water to the surface or surface waters to lands which are too high to be reached by the ordinary gravity method throughout. There are other uses, however, to which this energy can be economically applied. Taking these in the sequence of events they may be summed up as follows:

1. *Transportation.* This includes the building and operation of works for transporting material to be used in construction.

2. *Construction.* This embraces all electrical devices employed in the handling of materials, in lighting the works and in facilitating other operations.

3. *Pumping.* As previously stated this is the most important use of the electric energy which is developed in the course of the work of the Reclamation Service.

4. *Commercial.* An important outgrowth of the above is the disposal of excess electric energy developed largely in connection with pumping, but sold for lighting or industrial purposes, proceeds being used to assist in defraying the cost of the pumping of water for agricultural purposes.

Methods. The methods of development of electrical energy and the character of machinery employed are largely those of the usual commercial practise, the attempt being made to keep well in the lead. In some cases, notable advances have been made over customary methods. As might be inferred, the largest amount of energy is developed by the use of water power. In other words, hydroelectric planning and construction form the principal feature of this class of engineering works. There are, however, a number of relatively small plants in which the energy is derived from the consumption of fuel either utilized in the production of steam or in the more direct use of oil or gas in the ordinary engines developed for this purpose.

Costs. In all of this work undertaken by the Reclamation Service, not only in connection with electrical development and

use, but also in its other operations, careful records are maintained of the actual cost of the various items. Quite frequently in statements of cost prepared by other bureaus of the government, the matter of overhead charges has been neglected or many items which are properly to be considered in this connection are not entered because they are carried on regular appropriations. These neglected items usually consist of salaries of permanent officials whose time is largely devoted to the particular work in hand but is not charged to it. For this reason, the costs prepared by the Reclamation Service give, perhaps, a more accurate conception of actual and necessary expenditures than those usually obtainable from records kept by government bureaus.

Without entering into an elaborate discussion of these costs, it may be said that they range, in general, from a few mills, or even less, per kilowatt hour for power developed in large quantities by hydroelectric plants, up to a few cents per kilowatt hour as developed by steam plants.

The costs for 1913 are shown in the following table:

POWER PLANTS OPERATED BY RECLAMATION SERVICE IN 1913.

Reclamation project	Power plant	Location	Type	Capacity kw.	Annual load factor per cent.	Output in kw-hr.	Cost in cents per kw.hr.-(a)
Salt River.....	Three Plants	Arizona	Hydro-elec	8,560	12.7	9,518,570	0.810
Boise.........	Boise	Boise R. Idaho	"	1,875	43.2	7,082,123	0.268
Minidoka.....	Minidoka	Snake R. Idaho	"	7,000	46.1	28,265,287	0.126
Truckee-Carson	Lahontan	Lahontan Nevada	"	1,250	8.5	930,360	1.118
Rio Grande....	Elephant Butte	Elephant Butte Dam New Mex.	Steam turbine elec.	1,875	12.6	2,065,840	2.873
No. Dakota Pumping......	Williston	Near Williston ND	"	1,150	11.4	1,145,337	2.614
Strawberry Valley....	Spanish Fork	Near Sp. Fork, U	Hydro-elec.	850	11.6	861,705	2.572(b)

(a) These costs are at power plant switchboards and include in addition to all maintenance and operating expenses, general expense and plant depreciation.
(b) Includes heavy canal expense.

For purposes of comparison with the above statements of cost, it may be said that it is a popular belief that the cost of manufacturing electric power at Niagara Falls is about 0.2 cent

per kilowatt-hour, and that for power development in blocks of say 5000 kilowatts and upward, it is more economical to erect a modern steam power plant at Buffalo than it is to transmit this energy from Niagara Falls at a cost at Buffalo of say $2\frac{1}{2}$ mills per kilowatt-hour. In other words, the modern economy of the steam engine and generator is such that when fuel is cheap, current can be manufactured on the ground and utilized without transformation more economically than it can be transformed and transmitted over a considerable distance. The cheapest hydroelectric power reported is in the South, stated at 0.1 cent per kilowatt-hour, or about $6 per h.p. per year.

On the Minidoka Project of the Reclamation Service, the cost of producing power at the plant switchboard is seen from the above table to be about $1\frac{1}{4}$ mills. The surplus power over that needed for irrigation pumping on this project is sold as a by-product. For this purpose the Reclamation Service contracts with a local company or distributor, protecting the ultimate consumer by provision in the contract limiting the maximum rates chargeable by the distributor. These rates are shown in the table on the following page.

Fallacies. In developing hydroelectric power for irrigation pumping, it has been necessary to meet many popular fallacies concerning the cheapness of water power. It is generally assumed that because the water is flowing more or less continuously throughout the year, making possible a large amount of power, that therefore, the power itself must necessarily be cheap. Little consideration is given to the large first cost of installation, of development of the power, of the interest on the investment and particularly to the depreciation.

Few people outside of the profession of electrical engineering understand that the utilization of the natural water power is accompanied by heavy expense, notably in fixed charges for interest and depreciation, and that these may far exceed the more obvious costs of a steam plant. Obsolescence also must be considered, especially in waterwheel development. Great improvements have been made along that line, so important that no up-to-date power plant manager can ignor taking advantage of them. While in purely electrical apparatus obsolescence is becoming less and less of a large factor, if the plant is properly designed, yet it must be considered. The heavy item and one not usually appreciated is, as above stated, the interest, depreciation and other fixed charges inseparable from a large

capital investment. It is not an uncommon thing for a unit of hydroelectric power generation transmission and transformation at the substation to run into $250 to $300 per kw., while a steam plant in large sizes may not exceed $45 to $60, or at the most $75 per kw. On the other hand, the depreciation of a

IDAHO—MINIDOKA PROJECT.
Electric Power for Commercial Use.
(Contracts Nos. 322, 323 & 326 and supplemental contracts.)

Monthly Rates.			
To distributor		To consumer	
Per incandescent light of 15 watt.....	$0.03	For 20 incandescent, 15 watts ..... 5c, each additional light	$1.50
Per incandescent light of 15-60 watts...	.10	For 5 incandescent, 15-60 watts.... 25 c. each additional light	1.50
Per incandescent light over 60 watts... for each 60 watts or frac.	.10	Per light over 60 watts......... for each 60 watts or frac.	.25
Per arc light, 700 watts to 10 p. m......	1.50	Per arc, 700 watts to 10 p. m........	2.50
Per arc light, 700 watts all night.......	2.50	" " " " all night.........	4.00
Heating Rates.			
Per device, Sept. 1—June 1...........	$0.50	Per device 1000 watts Sept. 1-June1	$1.00
Per device per 1000 watts June 1—Sept. 1,..................	1.50	Per device per 1000 watts June 1—Sept. 1,...............	2.50
Flat Iron Rates			
Per flat iron 700 watts...............	$0 25	Per flat iron 700 watts............	$0.50
Metered light and appliance rates, per kw-hr.			
First2,500 kw-hr in mo................	$0.027	First 25 kw-hr in mo......	0.07
For 2,500-5,000 kw-hr. in mo.........	.025	For 25-50 kw-hr in mo	.06½
For 5,000-10,000 " " "	.023	For 50-100 " " "...........	.06
In excess of 10,000 " " "	.021	In excess of 100 " "...........	.05½
Power Rates, per kw-hr.			
First 2,000 kw-hr. in mo.............	$0.01	First 100 100 kw-hr. in mo.........	$0.05
For 2,000- 3,000 (do)	.007	For 100-200 (do)...........	.04
For 3,000- 5,000 "	.0055	" 200-500 "	.03
		" 500-1000 "	.015
For 5,000-10,000 "	.0053	" 1000-2000 "	.008
		" 2000-5000 "	.007
For 10,000-25,000 "	.0051	" 5000-50000 "	.0063
		" 50000-75000 "	.0060
In excess of 25,000 "	.0050	" 75000-100000 "	.0057
		In excess of 100000 "	.0055

steam plant and repairs of the same are much in excess of the hydroelectric system as a whole, but this does not modify the fact that it is often cheaper to build steam plants to meet load conditions rather than to furnish it by hydroelectric power. This, as above stated, it is difficult to bring to public comprehen-

sion, namely, that electric power developed from water power is sometimes more expensive than the equivalent amount of power developed, when needed, by economically operated steam or gas engines.

One of the popular misapprehensions which has given rise to considerable disappointment to the settlers on government projects is the lack of appreciation of the fact that electric energy after being developed must be raised to high voltage for long distance transmission and again transformed before distributed to the consumer and that such transforming apparatus is quite expensive.

The farmer, seeing a high-tension line skirting his farm, cannot readily be made to understand why he cannot purchase a small amount of electricity for use on his farm or in his house. It is necessary to explain to him that the difference is almost as great as would be in a case where he might argue that because a tree grows on his land, he should be able to get his tables and chairs at relatively small cost! The transformation of a tree into a chair may be as difficult as the transformation of the high-tension electricity into a form such that he can safely use it around his house or barn.

There has also been an exaggeration in the minds of the people in the communities on some of the government projects of the importance to them of the power plants which have been built in connection with the pumping and related work. They seem to think that these are an asset which they can utilize for more or less speculative purposes and that the earnings of these power plants will notably reduce the cost of the irrigation works and possibly save the water users from any expenditure. They have an exaggerated idea of the earning power of these works, not appreciating that many of them can be operated only during the irrigation season, and that electric power developed under these circumstances has small commercial value. They have heard of the great earnings of the water power monopolies and picture to themselves the advantages of securing a monopoly of this kind which they can handle to their own immediate profit forgetting that the manufacture and sale of electricity developed by water power is a highly specialized business, like the manufacture of any other commodity, and one which is not always financially successful, and then only because handled by men of exceptional ability.

Uses. As above stated many of the uses for electric power

developed by the Reclamation Service are those in connection with transportation of materials and construction of works. There is not much of novelty to be considered in this connection, as the devices employed are usually standard in design. They consist of light electric railroads, such as are needed in construction of tunnels and in similar work, and apparatus for the operation of cement plants, cableways, hoists, excavating machinery etc., lighting plants being, of course, an important adjunct.

Pumping, however, forms the great and principal use of the electric power development and there were installed 9235 h.p. in permanent pumping plants used in 1913, in addition to numerous small drainage installations, semi-portable and intermittently used. The cost, including all overhead charges and depreciation has been estimated to average about one cent per acre-foot raised one foot, ranging from 0.3 cent per acre-foot at Minidoka, upward. That is to say an amount of water covering an acre one foot in depth, or 43,560 cubic feet, can be raised to a height of 50 feet for fifty cents.

In comparison with this, water raised by the ordinary small steam or gasoline pumping plant built by associations of farmers throughout the arid regions is probably costing from 7 to 10 cents per acre-foot raised one foot, including, as above stated, interest and depreciation. With better and more economical devices for raising larger quantities the cost may be cut down to five cents or even, under exceptional conditions, as low as 3 cents, while those of the government works, as above stated, may run as low as at Minikoda in 1913 when it averaged 0.346 cent.

Sales. Sales of power for commerical and other purposes are made at varying rates dependent mainly upon the cost of development. As a rule, the electric energy is sold by the government as nearly as possible at cost. The reason that the cost varies so widely is due primarily to the difference in conditions of development, and, secondarily, to the conditions attached to the sale, particularly as to the continuity of demand by the consumer.

The ordinary price or what may be considered as a standard of the Reclamation Service for current for commerical purposes in large lots is about 1.5 cents per kw-hr. Under extraordinary conditions where excess power is sold whenever developed and is used as an auxiliary for steam power, the price has been as low as 0.75 cent per kw-hr. or even 0.5 cent.

In one case in Utah the Reclamation Service is selling at 0.8 cent per kw-hr., with a guaranteed minimum charge of $225 per calendar month. While this is a comparatively low rate, it is not as low as the minimum rate given the Reclamation Service in purchasing power in Montana, where a company has built a considerable amount of transmission lines in order to secure the business of the Reclamation Service in the construction of the Sun River project.

The essential feature in these extraordinary low prices is that the Reclamation Service is selling surplus power and that there are two unusual clauses relieving the United States from obligation to furnish power in case it should become inconvenient to do so, as follows:

"The United States shall have the right and privilege to shut down its power plant and cease serving electric energy at any time in order to make necessary repairs or additions to transmission lines, canals, or machinery."

Also it is stated that "in case of the shortage of power due to lack of water, or if the demands for power for construction purposes causes the furnishing of power to the city to impede the progress of construction work on the project, the United States reserves the right and privilege to cut off the power until such time as it is possible to furnish power without impeding the progress of construction work."

The rates charged for heating and similar purposes vary widely as above noted, dependent upon there being an excess of energy during the winter season when water is not pumped for irrigation. Not being sold or disposed of for profit, the rates for sale approximate usually, as above stated, nearly the actual cost, these being so low in some cases as to compete with coal at $7 per ton in heating houses and in cooking.

Power Development. The following figures give in concise form and in alphabetic order by states the power already developed, together with the total proposed or possible power and the output. Following the tables there is also given a brief description of some of the more important power plants with their chief characteristics. The most notable of these is on the Salt River project in Arizona, the principal power plant being located at Roosevelt dam and the subsidiary power plants along the canals which are supplied with water largely from the reservoir created by this dam.

Power Development* (Water Power Unless Otherwise Specified).

Project.	Name of Plant.	Maximum head (feet)	Horse power	
			Prime-movers installed	Total proposed or possible
Arizona:				
Salt River	Roosevelt (a)	226	8,640	15,640
" "	So. Consolidated (b)	30	2,800	2,800
" "	Arizona Falls (c)	18	1,450	1,450
" "	Crosscut (d)	117	6,000	6,000
Arizona-Cal.:				
Yuma	Drop in Cal. Canal	9		1,000
"	Ariz	25		7,700
California:				
Orland		27		483
Colorado:				
Grand Valley	Main Canal	44		3,600
Uncompahgre				10,000
Idaho:				
Boise	Boise Dam (e)	30	2,550	2,550
"	Arrowrock Dam	230		17,000
"	Drops in canals	20–90		4,800
Minidoka	Minidoka Dam (f)	50	10,000	20,000
Kansas:				
Garden City	Deerfield (steam) (g)		700	700
Montana:				
Flathead	Flathead River	60		360,000
"	Revais Creek	1000		26,000
Huntley	Main Canal drop (h)	34	286	600
Montana, N. D.:				
Lower Yellowstone	Lateral K. K. drop			290
Nevada:				
Truckee-Carson	Lahontan (i)	120	1,800	6,000
" "	26-foot drop	26		2,000
New Mexico-Texas:				
Rio Grande	Elephant Butte (steam) (j)		2,000	2,000
" "	" " (hydroelec)			10,000
North Dakota:				
N. D. Pumping	Williston (steam) (k)		1,550	1,550
Oregon:				
Klamath	Various sites	22–88		9,700
Umatilla	Drainage outfall	28		145
Utah:				
Strawberry Valley	Spanish Fork (l)	125	1,600	3,500
Washington:				
Yakima.				
Sunnyside Unit	Drops in canals	20–88		1,800
Tieton Unit				3,250
Wapato Unit				9,000
Okanogan	Drop No. 1 (m)	105		250
"	" (n)	56		300
"	Salmon Creek	441		2,800
			39,376	532,908

*Power may be developed on other projects, but data not completed.
†Turbine capacity.
(a) Three 1680-h.p. and two 1800-h.p. turbines; five 1060-kw. generators.
(b) Two 1400-h.p. turbines direct connected; two 1000-kw. generators.
(c) Two 725 h.p. turbines direct connected; two 525-kw. generators.
(d) Six 1000-h.p. vertical tangential wheels; six 875-kw. generators.
(e) Three 850-h. p. turbines, direct connected; three 625-kw. generators.
(f) Five 2000-h. p. turbines, direct connected to five 1400-kw. generators.
(g) Two 350-h. p. steam turbines and two 225-kw. generators.
(h) Two vertical turbines, direct connected to two 20-inch centrifugal pumps, capacity 28 second-feet.
(i) Two 900-h. p. turbines direct connected to two 625-kw. generators.
(j) Three 625 kw. steam turbine units.
(k) Two 300-kw. and one 500-kw. steam turbine units.
(l) Two horizontal 800-h. p. turbines and two 500-kw. generators.
(m) One 250-h. p. turbine; one 187-kw. generator.
(n) 300-h. p. turbine; one 187-kw. generator.

Other interesting developments are those in southern Idaho; the larger on Snake River near Minidoka, and the smaller on; Boise River near the city of Boise. On several of the other projects, power plants have been constructed or are projected, notably in New Mexico at the large dam being built on the Rio Grande and in Utah on the Strawberry Valley project. In the State of Washington a number of small plants are under construction in connection with pumping extensions of the Yakima and Okanogan projects.

At each of the large storage dams, built by the Reclamation Service, there are opportunities for intermittent power, some of which will undoubtedly be utilized after this country has developed to a higher degree and markets are established.

The following extract from material for the forthcoming 13th Annual Report of the Reclamation Service gives in summarized form the capacity, output and construction costs for each of the more important power plants of the Service.

POWER PLANT DATA.

Project	Name of plant	Capacity kw.		Cost	Output kw-hr.	
		Rated	Safe observed		Sold	Used by Reclamation Service
RIZONA,						
Salt River....	Roosevelt	5300	6000	*$642,654.23	9,336,802	2,932,23C
	South Consolidated	2000	2000	162,123.05		
	Arizona Falls	1050	1000	109,500.73		
	Crosscut†	5250		incomplete		
IDAHO						
Minidoka	Minidoka	7000	7420	433,887.21	7,342,963	19,511,603
Boise........	Boise	1875	2400	168,446.05	2,529,422	4,937,031
NEVADA,						
Truckee-Carson.....	Lahontan	1250	1450	85,437.63	219,544	2,110,127
UTAH,						
Strawberry, Valley	Spanish Fork	1000	1000	55,531.71	687,780	156,674
NEW MEXICO,						
Rio Grande...	Elephant Butte (steam)	1875	1875	136,491.83	14,825	3,275,285
N. DAKOTA						
Williston, ...	Williston (steam)	1150	1550	228,699.39	436,300	559,003
Totals ...		22500	24695	$2,022,771.83	20,567,636	33,841,953

*Exclusive of power canal and diversion dam $1,500,459.01. To the cost of this power plant will be added $83,000 to cover a 5000-kw. unit now being purchased, making a total cost of $725,654.23, and a total rated capacityof 10,300kw.

†Not included in totals.

Arizona, Salt River Project. The power plants built in connection with the construction of the large Roosevelt dam and at several drops along the canals which distribute the water which has been stored behind the dam are among the most important built by the Reclamation Service. They illustrate the development of this somewhat peculiar type, the operation of which is necessarily made subsidiary or secondary to the use of water for irrigation. Here, however, where water is used throughout the year in irrigation the conditions to be met are less severe than those in Idaho where the water is only used during the summer months.

*" The government has built the Roosevelt dam in the canyon of Salt River, 78 miles above Phoenix, to store over a million acre-feet of water for irrigation in the valley below. The dam is 280 feet high, affording a high head for a hydroelectric power plant. A plant was built below the dam to take advantage of this opportunity to furnish power for pumping underground water to irrigate additional land beyond the capacity of the gravity water supply. A 10-foot penstock through the dam operates machines under a variable head as the water is drawn out of the reservoir.

" The system also includes a power canal of 225 second-feet capacity and 19 miles long around the reservoir, making it possible to get the full head of the dam with the normal flow of the stream at all times. The power canal was built before the dam to furnish power for the construction of the dam itself, so that part of the original cost of the canal really belongs to the dam. The power house at present contains five machines capable of delivering about 5000 kilowatts, and it is intended to install a large machine this year that will bring the total output up to about 10,000 kilowatts. In the valley, the farmers have assessed themselves for money to build three other power plants in places where there is fall in the canal system, having a total capacity of 8000 kilowatts. When the plants now under way are completed the power system will represent an outlay of approximately $3,500,000, including the cost of the power canal. All of these plants are connected by a distributing system consisting mainly of 168 miles of steel tower, 45,000-volt transmission line and about 40 miles of 10,000-volt distributing line. The

*Abstract of article on the Salt River Valley power situation prepared by Mr. Wm. F. Cone and printed in the Reclamation Record for May 1914.

surplus power over that required for irrigation is sold and the receipts go to reduce the cost of the project as charged against the land irrigated.

" Substations at Phoenix, Chandler, Glendale, Sacaton and Miami are distributing current for various uses. At Phoenix, all the lighting and electric power in the vicinity is supplied by the Government and is used for lighting the city, operating the street railway, ice plants, alfalfa mills and a cement mill. At Chandler, the power is used almost altogether for pumping. At Glendale, the Government supplies power for lighting the city of Glendale, operates several motors for different purposes and also takes care of a large pumping section just outside the project in what is known as the Marionette district. At Sacaton, power is furnished the Indian reservation for 10 irrigation pumping plants, for domestic water supply, and for lights at the Agency and School. At Miami the Inspiration Consolidated Copper Company is now putting in a large mill for handling low grade copper ore. This mill covers eight acres of land, all under one roof. The company will also operate a smelter, the mine machinery, hoists, lighting systems, compressors, and other devices by means of power from the Government system.

"In addition to the above-mentioned uses, the farmers in one section of the valley, are now planning to put in a distributing system of their own, covering about 40 sections of land and bringing the power to their homes for pumping domestic water and doing general work around the farms, such as lighting and cooking."

Idaho, Boise Project. In connection with the construction of the Arrowrock dam, said to be the highest in the world, a power plant has been built on Boise River about 18 miles below the site, power being transmitted to the dam for use in construction. After the dam is built there will probably be installed at the reservoir itself a power plant capable of developing about 5000 h.p., which will be used in connection with the power plant now constructed at the lower point on the Boise River for supplying power for pumping water for irrigation and for commercial purposes.

*Idaho, Minidoka Project.** This is one of the largest and most interesting developments of hydroelectric power made by the

*See detailed statement by Barry Dibble in *Journal of Electricity, Power, and Gas*, July 11, 1914.

Reclamation Service. The power house is at a dam which was constructed across Snake River for the purpose of diverting water by gravity to 70,000 acres. This dam has a maximum height of 86 feet and a length of 937 feet. In addition there is a concrete spillway about half a mile in length on which the water can be controlled by flashboards thus adding needed storage. The drainage area above this diversion dam is 22,600 square miles. The normal floods occur in June and usually reach a peak of some 30,000 to 40,000 second-feet. In low-water stage, which follows soon after in July and August, the river drops to 2000 second-feet, although from 2500 to 3000 is a usual minimum.

At all times water must pass this dam, as there are prior water rights to the amount of 3400 second-feet, so that all of the flow up to this amount during the irrigation season must be passed for the use of the lands below if needed by them. This has necessitated the development of storage on the head-waters of Snake River in Wyoming, about 300 miles above the Minidoka dam. This storage is created at Jackson Lake in Wyoming, where by building a low dam an available capacity of 380,000 acre-feet has been obtained, this being in addition to the 53,500 acre-feet which can be held in Lake Walcott immediately above the Minidoka dam and power house.

On the north side of the river, water is diverted by gravity to irrigate about 70,000 acres of land. On the south side, the water diverted by the dam is used mainly to supply lands which lie above the gravity supply and to which the water must be lifted by pumping, utilizing for this purpose the power developed at the dam through the use of the water which must be passed down the river for the lands farther down the stream.

The power is developed under a head of 46 feet and the plant consists of five principal units each having a capacity of 2000 h.p. in the water turbine. These turbines drive electric generators which have a normal capacity of 1200 kw. each and which under a high head have delivered as much as 1600 kw. each.

The storage lake immediately above the dam known as Lake Walcott covers 10,000 acres, and is used in summer time as an auxiliary storage in which the water can be raised five feet above the spillway crest of the dam by means of flashboards. When the lake is thus raised additional head is made available at the power house to increase the capacity of the plant. Water is taken from the lake to the turbines through 10 ft. penstocks,

each of which carries approximately 500 cu. ft. per second, when operating at full capacity.

Electric energy is generated at 2200 volts, carried by cables through fibre conduits to air-cooled transformers, which raise voltage to 33,000 volts for transmission.

All the wiring and switching beyond the transformers is in duplicate, and all the way through the greatest precautions are taken to prevent any accident. The variation of load on the power house is extreme, the greatest demand being during the heat of the summer when water is needed for irrigation. Great fluctuations are caused by occasional rains which lessen the irrigation demand.

During 1913, the output of the station reached 28,265,287 kw-hr., with an observed peak of 7420 kw., making the annual load factor nearly 40 per cent. The annual cost of operation and maintenance amounted to practically $16,000, or less than 0.07 cents per kw-hr., independent of fixed charges. Including fixed charges, general expense and depreciation, cost in 1913 was 0.126 cent per kw-hr.

From the power house, two transmission lines extend over the project crossing the river and uniting so as to form a loop over which the current can be supplied. There are about 62 miles of 30,000-volt lines and over 20 miles of 2200-volt lines, supplemented by distribution systems in the towns and owned directly by settlers. The annual cost of operating and maintaining the high-tension lines is about $40 per mile.

The pumping stations which supply water to approximately 48,000 acres of land are the largest which have been built for irrigation purposes. It is believed that the pumping stations for the city of New Orleans which are used in the case of severe rainstorms to remove the storm water from the sewers of the city, are the only pumping stations in the United States which have a larger capacity than those on the Minidoka project. The station buildings, which are of concrete, contain transformers for lowering the voltage from 30,000 to 2200, and also house the motors and pumps.

There are ten pumps which were originally of 125 second-feet capacity, each driven by a 600-h.p. motor and two 75-second-foot pumps driven by 360-h.p. motors. At each station the lift is approximately 30 ft. so that the lift of the third canal is nearly 90 ft. above the gravity supply.

Approximately 127,000 acre-feet of water were pumped during

the season of 1913, and of this, 17 per cent were used on the 30-ft level, 36 per cent on the 60-ft. level and 47 per cent, or nearly one-half, on the 90-ft. level.

The average lift for the season was 68.3 ft. The power required was nearly 16,000,000 kw-hr. with a peak of 6550 kw., corresponding to a load factor of 27.7 per cent. The cost of operating and maintaining the three stations was $13,000, exclusive of the fixed charge and of the cost of power or a trifle more than 10 cents per acre lifted the average height. The cost of operation and maintenance of the canal system amounts to an additional 75 cents per acre.

There has been very heavy demand on the pumping stations for a week or ten days in the middle of the summer and at this time all of the machinery has been pushed to its fullest capacity. Efforts are being made, however, to arrange by rotation of delivery of water to spread the demand over a longer period without hardship to the farmers and avoid the excessive demands for the very short period.

During the winter of 1913-14, alterations have been made in the runners of several of the large pumps and recent tests indicate that the changes will increase the capacity from 125 to 165 second-feet and improve the efficiency of the pumps from 72 per cent to over 80 per cent.

North Dakota, Williston Pumping Plant. This plant although relatively small in size is of peculiar interest because of the fact that the government owns and operates the coal mines which supply the fuel, this being dug immediately adjacent to the power house, and the coal carried immediately from the mine through crushers into the hoppers which supply the furnaces. Burned there, the steam generated is used in turbines, which in turn convert the energy into electric power which is transmitted from the power house down to the Mississippi River, is carried out onto barges which contain pumps which in turn lift the water from the river to settling basins on the land from which it can flow by gravity back to the power house, be there picked up by suitable pumps, raising it about 30 ft. from which level it flows to the lands to be irrigated.

In addition to the power which is used during the summer to pump water for irrigation, there has been provided an all-the-year-round load by making arrangements with the City of Williston for sale of power for lighting the city and for other purposes. It has been found that a government bureau is not the ideal form of organization to economically handle the retailing of

electrical power to small consumers. Therefore, the policy has been adopted of aiding the farmers and local people to form mutual companies to build their own lines to connect with the government system, install their own house transformers, and handle the retailing of the power.

Conclusion. In what has been stated above, sufficient detail has been given to illustrate the general character and extent of the works being built by the government through the Reclamation Service and to indicate the policy which up to the present time has been found advantageous. A certain amount of experience has been acquired in this class of development work and the demonstration made that it is possible for the government to build and operate works at a cost comparable to the outlay by ordinary corporations. The results, therefore, have peculiar interest to the citizens of the country as showing what may be done and also the difficulties to be avoided in governmental operations of this kind where the question of profit and interest on the investment is not considered, but rather the general benefit in upbuilding a community under pioneer conditions. When these communities are upon their feet, it is the intent of the law that all of these works be turned over to the landowners and be maintained by them at their own expense, under such regulations as may be desirable at the time. It is to be noted that these landowners are to pay for the actual cost of the work in annual installments which, under the terms of the act of August 13, 1914, have been extended from 10 years to 20 years, without interest on the deferred payments.

The employes of the Government engaged in the construction and operation of these works at all times stand ready to assist the small subsidiary companies or organizations of farmers and water users to build their own lines, to make repairs, and in fact to aid them in every way possible, usually taking the initiative in urging the farmers to find new uses for power. So that ultimately, when the hydroelectric works or big power plants are turned over to the organizations of farmers they will have had experience adequate to operate them through the employment of competent electricians. At present the rural lines cannot be considered a profitable investment from a power company's standpoint. However, they enhance the value of the farms which are reached by the lines and the material saving to the farmers which comes from use of electricity makes the investment a good one from the farmers' standpoint.

Presented at the Seattle Section meeting of the American Institute of Electrical Engineers, Seattle, Wash., May 19, 1914.

(*Subject to final revision for the Transactions.*)

EFFECT OF ELECTROLYSIS ON THE COMPRESSIVE STRENGTH OF CEMENT AND CONCRETE

BY C. EDWARD MAGNUSSON AND B. IZHUROFF

ABSTRACT OF PAPER

A paper on "The Electrolytic Corrosion of Reinforced Concrete" by C. E. Magnusson and G. H. Smith was read before the A. I. E. E. June 30, 1911, and, as stated in that paper, the results could not be pronounced entirely conclusive, as the duration of the experiments was only 30 days. In the present paper a similar series of experiments is described by the authors in which the tests were continued for several months. The paper gives in tabular form the result of a large number of experiments and the conclusions corroborate the results reported in the former paper.

For the current density covered by the experiments, the current was found to produce no change in the compressive strength of concrete cubes, from which it is deduced that the failures of reinforced concrete due to electrolysis are due entirely to the forces produced by the increase of volume when iron is changed into iron oxide, and not by any direct action of the current upon the concrete.

THE results of a preliminary test made in 1911 on the effect produced by an electric current on the compressive strength of cement and concrete were included in a paper on "Electrolysis in Reinforced Concrete."* As stated in that paper, the experiments were of too short duration, thirty days, to make the results conclusive. In order to secure more evidence a new series was begun in September 1912. The method used was essentially the same as in the preliminary series. A better means for keeping the cubes moist was devised; also by tightly wrapping the cubes with rubber and friction tape, practically all the leakage was eliminated, so that all of the current in each circuit passed through the four cubes in series.

Unless exception is noted the following conditions will apply:

(1) The cement used was of the "Washington" brand, manufactured at Concrete, Washington. This brand is of good commercial quality, and is used extensively in the Puget Sound region. The tensile strength complies with the specifications for Standard Portland cement, as given by the American Society

*A. I. E. E. TRANS. Vol. XXX, p. 2055.

for Testing Materials. Chemical analysis and physical test data for this cement are given in Table 1.

TABLE I

Chemical analysis and physical test of the cement.

SiO_2		21	per cent
AlO_3		7	per cent
Fe_2O_3		2	per cent
CaO		66.5	per cent
MgO		1	per cent
SO_4		0.5	per cent
Na_2O and K_2O		2	per cent
Specific gravity			3.12
Fineness:—			
Weight of sample	50.0 gr.		
Aver. of 3 sample: retained on 200 mesh	7.9 gr.,	14	per cent
" " 100 "	0.29 "	0.58	per cent
" " 50 "	0.02 "	0.04	per cent
Normal consistency 400 gr. cement, 88 gr. water		21.6	per cent
Penetration	10.5		
Tensile Strength:—			
Aver. of 3 sample: 24 hours	108 lb.		
7 days	499 "		
28 days	717 "		

(2) The "fresh water" used was from Cedar River; the data from a chemical analysis and specific resistance are given in Table II.

TABLE II

Chemical analysis of Cedar River water expressed in milligrams per liter.

Nitrics	0.0
Nitrates	0.0
Free ammonia—a trace	
Albumenoid ammonia	0.0
Free oxygen	0.8
Chlorine	3.5
Total solid	41.0
Fixed solid	21.0

Electrical conductivity per cm^3	at 20 deg. cent.	at 30 deg. cent.
Cedar River water	20,100 ohms	15,600 ohms.
Fifth normal NaCl solution	54.4 "	45.4 ".

(3) The "salt water" used was a 3 per cent NaCl solution in Cedar River water.

(4) Natural sand, screened to pass a sieve having 20 meshes per linear inch and retained on a sieve having 30 meshes, was used.

(5) The gravel was screened to pass a sieve having 4 meshes per linear inch, and retained on a sieve having 8 meshes.

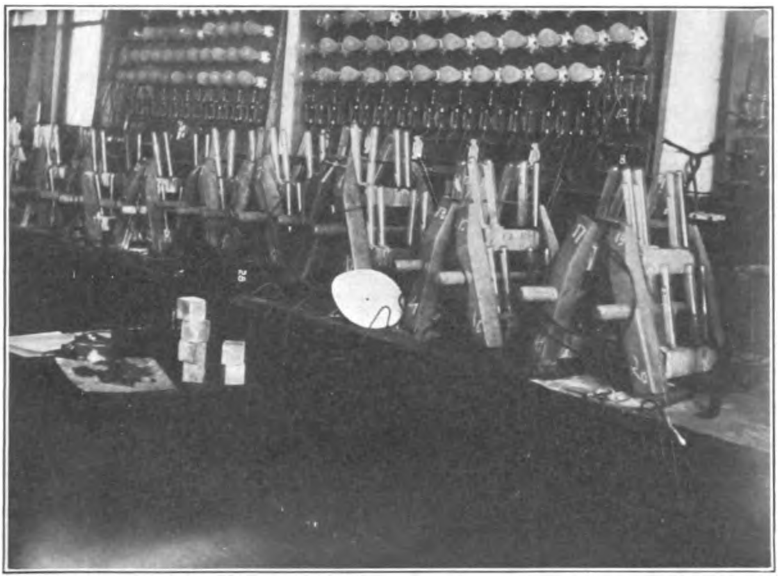
Two hundred and forty 2-inch (5-cm.) cubes were made as follows:

(a) Sixty cubes of cement with "fresh water."

(b) Thirty-six cubes of mortar with "fresh water."

Ratio of cement to sand, 1: 3.

PLATE C
A. I. E. E.
VOL. XXXIII, NO. 10



[MAGNUSSON AND IZHUROFF]

FIG. 1—ARRANGEMENT OF TEST APPARATUS

(c) Twenty-four cubes of concrete with "fresh water."
Ratio of cement: sand: gravel = 1:1:1
(d) Sixty cubes of cement in "salt water."
(e) Sixty cubes of concrete in "salt water."
Ratio of cement: sand: gravel = 1:1:1

The cubes were made in accord with the specifications of the Committee on Uniform Testing of Cement, American Society of Civil Engineers.

Six bronze molds were used and six cubes were made at a time, and in the tables this is termed a "set." In making the cubes due care was taken to secure uniform conditions. The consistency was adjusted to give a reading of ten on the scale of a Vicat needle. The cubes were kept in the molds, under cover of a damp cloth to keep the air moist, for 24 to 28 hours.

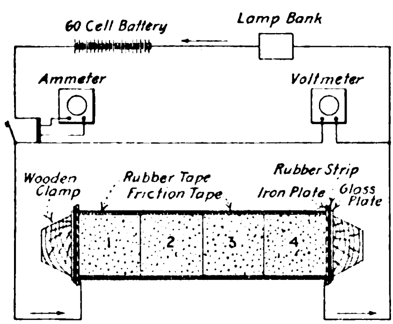


FIG. 2

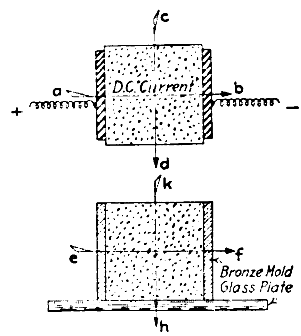


FIG. 3

At removal from the molds each was numbered, and then immersed in water, "fresh" for groups (a), and (b), and (c), and "salt" for (d) and (e), where they were kept for forty to sixty days, as recorded in Tables VII to X.

Four cubes from each set were then placed in the electric circuit; No. 1 nearest the anode, next No. 2 and No. 3 with No. 4 nearest the cathode. The remaining two cubes, No. 5 and No. 6, were kept in the water as control. As the four cubes in the electric circuit were kept moist throughout the experiment the only factor affecting cubes No. 1-4 more than No. 5-6 would be the electric current passing through the former.

The arrangement of the cubes and the wiring are shown in Fig. 2. At each end an iron plate was placed, extending a little beyond the surface of the cubes, and having a copper wire soldered to one edge for electrical connection. A glass plate

and a rubber strip were placed outside the iron for insulation and the whole secured by a wooden clamp. By means of this clamp pressure could be applied so as to give a fairly good contact between the iron plates and the cubes, and also to bring the four cubes into close contact. The sets were wrapped tightly with rubber tape, and this secured by friction tape. In order to keep the cubes moist small openings were made through the tape on top of the cubes. These openings were covered by inverted test tubes, full of water, salt or fresh according to which had been used in making the cubes. See Fig. 1. Absorbent cotton was placed under the test tubes and in this way the water could slowly seep through the cotton and keep the cubes moist. A storage battery of 60 cells in series with a lamp bank was connected to the iron plates. The voltage was applied continuously.

The currents in the circuits were characteristically irregular.

The iron plates corroded at the anode ends of all the sets. In the salt water sets the corrosion was much more rapid than with the fresh water cubes. The cotton under the test tubes near the anode became saturated with the iron oxide. In the salt water sets the discoloring appeared in a few hours while with the fresh water three or four days were required. In set No. 7 the cotton was colored a greenish blue or Fe_3O_4 while all the rest showed the red color of Fe_2O_3.

No odor was noticeable from the fresh water cubes. The chemical reactions probably consist simply of a decomposition of water and the formation of iron oxide.

$$3\,H_2O \longrightarrow 6\,H + 3O$$
$$3O + 2\,Fe \longrightarrow Fe_2O_3$$

No tests were made to determine a possible migration of sulphates and other salts.

An odor of chlorine accompanied the reactions in the salt water sets. The following equations give the main reactions:

$$4\,NaCl \longrightarrow 4\,Na + 4\,Cl$$
$$4\,Cl + 2\,H_2O \longrightarrow 3\,H\,Cl + H\,ClO + O$$
$$H\,Cl\,O \longrightarrow H\,Cl + O$$
$$2\,Fe + 3O \longrightarrow Fe_2\,O_3$$
$$Fe_2O_3 + 6\,H\,Cl \longrightarrow 2\,Fe\,Cl_3 + 3\,H_2O$$

The chlorine odor indicates the presence of hydrochloric acid and this may cause a secondary reaction that might affect the crushing strength of the cubes.

TABLE III

Compressive strength of cement cubes made in fresh water.

Cube Nos.		Direction of crushing	Compr. str. in pounds.	Compr. str. lb. per sq. in.	Compr. str. kg. per cm.[2]
Set No. 1	1	ab	48,580	12,145	851
	2	ab	47,380	11,845	832
	3	ab	38,950	9,737	684
	4	ab	49,000	12,250	860
	5	kh	42,720	10,680	750
	6	kh	53,570	13,392	940
Set No. 2	1	cd	43,040	10,760	756
	2	cd	46,980	11,745	824
	3	cd	43,630	10,907	765
	4	cd	40,160	10,040	704
	5	ef	36,650	9,163	644
	6	ef	50,770	12,693	890
Set No. 3	1	ab	35,720	8,930	626
	2	ab	39,870	9,967	700
	3	ab	35,220	8,805	618
	4	ab	35,020	8,755	615
	5	kh	40,650	10,162	713
	6	kh	31,840	7,960	559
Set No. 4	1	cd	30,530	7,630	535
	2	cd	38,190	9,548	670
	3	cd	29,290	7,323	514
	4	cd	35,430	8,857	622
	5	ef	29,350	7,337	515
	6	ef	24,730	6,183	434
Set No. 5	1	ab	35,250	8,812	619
	2	ab	40,240	10,060	706
	3	ab	30,700	7,675	539
	4	ab	34,630	8,657	607
	5	kh	38,000	9,500	667
	6	kh	28,730	7,183	503
Set No. 6	1	cd	31,740	7,935	556
	2	cd	39,350	9,837	690
	3	cd	43,550	10,888	765
	4	cd	40,340	10,085	707
	5	ef	30,470	7,618	535
	6	ef	45,560	11,390	800
Set No. 7	1	ab	41,760	10,440	734
	2	ab	35,140	8,785	616
	3	ab	36,030	9,008	633
	4	ab	44,290	11,072	778
	5	kh	40,000	10,000	702
	6	kh	29,750	7,438	522
Set No. 8	1	cd	45,770	11,443	801
	2	cd	35,520	8,880	623
	3	cd	38,640	9,660	678
	4	cd	34,510	8,627	605
	5	ef	40,050	10,012	704
	6	ef	46,380	11,595	813
Set No. 9	1	ab	41,660	10,415	730
	2	ab	42,920	10,730	752
	3	ab	41,355	10,339	725
	4	ab	44,440	11,110	779
	5	ab	47,050	11,762	827
	6	ab	42,140	10,535	740
Set No. 10	1	cd	32,800	8,200	576
	2	cd	40,480	10,120	710
	3	cd	43,775	10,944	768
	4	cd	42,450	10,612	744
	5	ef	39,160	9,790	687
	6	ef	40,760	10,190	715

TABLE IV
Compressive strength of concrete cubes in fresh water.

Cube Nos.		Direction of crushing	Compr. str. in pounds.	Compr. str. lb. per sq. in.	Compr. str. kg. per cm.²
Set No. 11	1	ab	5,470	1,363	96
	2	ab	5,430	1,358	95
	3	ab	5,780	1,445	102
	4	ab	4,000	1,000	70
	5	kh	5,090	1,273	89
	6	kh	7,340	1,835	129
Set No. 12	1	cd	6,800	1,700	119
	2	cd	6,685	1,671	117
	3	cd	6,800	1,700	119
	4	cd	7,820	1,955	137
	5	ef	6,260	1,565	110
	6	ef	8,000	2,000	141
Set No. 13	1	ab	6,360	1,590	112
	2	ab	9,120	2,280	160
	3	ab	9,290	2,323	163
	4	ab	10,390	2,592	183
	5	kh	10,100	2,525	178
	6	kh	7,810	1,952	137
Set No. 14	1	cd	8,980	2,245	158
	2	cd	10,000	2,500	176
	3	cd	10,830	2,707	190
	4	cd	11,760	2,940	206
	5	ef	8,010	2,003	141
	6	ef	11,000	2,750	193
Set No. 15	1	ab	5,500	1,375	97
	2	ab	5,750	1,437	101
	3	ab	5,670	1,418	99
	4	ab	7,740	1,935	136
	5	ab	5,590	1,398	98
	6	ab	6,000	1,500	105
Set No. 16	1	cd	13,480	3,370	237
	2	cd	8,900	2,225	156
	3	cd	12,210	3,042	214
	4	cd	8,970	2,243	158
	5	ef	10,680	2,670	188
	6	ef	11,570	2,892	203
Set No. 17	1	ab	14,300	3,575	251
	2	ab	12,220	3,055	215
	3	ab	11,840	2,960	208
	4	ab	10,810	2,703	190
	5	kh	12,390	3,098	217
	6	kh	10,530	2,632	185
Set No. 18	1	cd	14,470	3,618	254
	2	cd	18,650	4,662	328
	3	cd	17,380	4,345	305
	4	cd	16,740	4,185	294
	5	ef	14,080	3,520	247
	6	ef	12,250	3,063	215
Set No. 19	1	ab	12,900	3,225	226
	2	ab	19,590	4,897	344
	3	ab	19,860	4,965	349
	4	ab	19,470	4,868	342
	5	ab	16,230	4,058	286
	6	kh	19,760	4,940	347
Set No. 20	1	cd	12,370	3,092	217
	2	cd	14,230	3,557	250
	3	cd	9,850	2,463	173
	4	cd	12,980	3,245	228
	5	ef	13,860	3,465	243
	6	ef	13,170	2,392	231

Testing Cubes

Finally, the cubes in the electric circuit and the controlling cubes were tested for their compressive strength, using a Riehle 60,000-lb. testing machine. All cubes were tested under as nearly identical conditions as possible, using the same machine and at the same speed. In Tables III to VI inclusive are recorded the crushing strength of all the cubes tested. Numbers 1, 2, 3, 4 in each case have been in the electric circuit. One half of the tested cubes was crushed in the direction of the flow of the current, and the other half was tested in direction perpendicular to the flow of the current. One half of the control cubes was crushed in the direction of the open ends of the bronze mold and the other half in the direction of the sides of the mold. In Fig. 3 and in Tables III to VI, the corresponding directions with letters are given. In Tables VII to X inclusive are given the data for each set.

Summary

(a) The compressive strength of fresh water cement cubes was not affected by an average current density of 1.2 milliamperes per square inch (0.17 milliampere per cm^2) applied for 310 days. Tables III and VII.

(b) The compressive strength of fresh water concrete cubes was not affected by an average current density of 1.8 milliamperes per square inch (0.26 milliampere per cm^2) applied for 225 days. Tables IV and VIII.

(c) The compressive strength of salt water cement cubes was probably not affected by an average current density of 10.2 milliamperes per square inch (1.4 milliampere per cm^2) applied for 113 days. Tables V and IX.

(d) The compressive strength of salt water concrete cubes was not affected by an average current density of 13.8 milliamperes per square inch (1.9 milliampere per cm^2) applied for 110 days. Tables VI and X.

For (a), (b), (d) the average values for the cubes treated with the electric current were 1, 2, 3.0 and 2.5 per cent respectively stronger than the corresponding control cubes. For group (c) the cubes in the electric circuit were 14 per cent weaker than the control. An examination of the crushing strengths in Table V will show that the apparent decrease is most likely due to a chance selection of too many of the stronger cubes for the control. If any action were due to the current the liberated

TABLE V

Compressive strength of cement cubes made in salt water.

Cube Nos.		Direction of crushing	Compr. str. in pounds.	Compr. str. lb. per sq. in.	Compr. str. kg. per cm.²
Set No. 21	1	ef	34,400	8,600	604
	2	ef	33,845	8,461	595
	3	ef	31,900	7,975	561
	4	ef	27,140	6,785	475
	5	ef	39,305	9,828	690
	6	ef	40,510	10,128	712
Set No. 22	1	kh	19,570	4,893	344
	2	kh	30,610	7,652	537
	3	kh	39,355	9,839	690
	4	kh	27,375	6,844	480
	5	kh	39,540	9,885	694
	6	kh	38,710	9,678	679
Set No. 23	1	ab	18,895	4,723	332
	2	ab	27,195	6,799	476
	3	cd	35,790	8,947	627
	4	ab	28 500	7,125	500
	5	ef	34,520	8,630	605
	6	ef	36,450	9,113	640
Set No. 24	1	cd	35,455	8,864	622
	2	ab	22,440	5,610	394
	3	ab	31,970	7,992	560
	4	ab	24,880	6,220	437
	5	ef	37,800	9,450	664
	6	ef	32,400	8,100	568
Set No. 25	1	bd	27,890	6,973	490
	2	ab	29,925	7,324	514
	3	ab	24,510	6,127	430
	4	ab	20,570	5,142	361
	5	ef	41,270	10,318	724
	6	ef	31,720	7,930	555
Set No. 26	1	cd	36,385	9,096	637
	2	cd	34,480	8,620	695
	3	cd	33,270	8,318	584
	4	cd	31,580	7,895	554
	5	kh	37,190	9,297	652
	6	kh	31,330	7,833	550
Set No. 27	1	cd	38,328	9,580	673
	2	cd	34,300	8,575	602
	3	cd	33,325	8,331	585
	4	cd	33,390	8,348	586
	5	ef	36,525	9,131	640
	6	ef	28,250	7,063	496
Set No. 28	1	cd	28,160	7,040	493
	2	ab	22,240	5,560	390
	3	ab	20,550	5,138	360
	4	ab	31,920	7,980	560
	5	ef	36,900	9,225	647
	6	ef	33,780	8,445	592
Set No. 29	1	cd	42,190	10,548	740
	2	cd	35,180	8,795	617
	3	cd	35,720	8,930	626
	4	cd	40,775	10,194	715
	5	ef	35,860	8,965	630
	6	ef	33,220	8,305	582
Set No. 30	1	ab	25,920	6,480	455
	2	ab	25,360	6,340	445
	3	ab	38,030	9,508	667
	4	ab	37,470	9,367	657
	5	kh	36,730	9,183	644
	6	kh	33,355	8,339	585

TABLE. VI
Compressive strength of concrete cubes made in salt water.

Cube Nos.		Direction of crushing	Compr. str. in pounds.	Compr. str. lb. per sq. in.	Compr. str. kg. per cm.[2]
Set No. 31	1	ab	14.230	3,558	250
	2	ab	18,685	4,671	328
	3	ab	24,110	6,027	423
	4	ab	18,675	4,669	328
	5	ef	12,740	3,185	224
	6	ef	20,940	5,235	367
Set No. 32	1	cd	21,550	5,387	378
	2	cd	20,810	5,202	365
	3	cd	16.210	4,052	285
	4	cd	18,870	4,718	331
	5	ef	18.630	4,657	327
	6	ef	21,280	5,320	374
Set No. 33	1	ab	15,540	3,885	273
	2	ab	22,200	5,550	390
	3	ab	20.230	5,056	355
	4	ab	21,340	5,335	374
	5	kh	18.100	4,525	318
	6	kh	22,620	5,655	397
Set No. 34	1	cd	13,385	3,346	235
	2	cd	14,185	3,546	249
	3	cd	14,880	3,720	261
	4	cd	15,930	3,982	280
	5	kh	12,550	3,138	220
	6	kh	14,200	3,550	249
Set No. 35	1	ab	16,220	4,055	285
	2	ab	23,275	5,819	408
	3	ab	25,330	6,332	445
	4	ab	22,380	5,595	393
	5	ef	17,380	4,345	305
	6	ef	21,330	5,332	374
Set No. 36	1	cd	23,325	5,831	410
	2	cd	19,120	4,780	336
	3	cd	19,780	4,945	347
	4	cd	26,690	6,672	468
	5	ef	23,720	5,930	416
	6	ef	24,500	6,125	430
Set No. 37	1	cd	21,900	5,475	384
	2	cd	18,140	4,535	319
	3	cd	18,920	4,730	332
	4	cd	16,120	4,030	283
	5	kh	16,140	4,035	284
	6	kh	18.200	4,550	320
Set No. 38	1	ab	15,565	3,891	273
	2	ab	13,625	3,406	239
	3	ab	11,545	2,886	203
	4	ab	12,370	3,092	217
	5	ef	14,260	3,565	250
	6	ef	13,270	3,318	233
Set No. 39	1	cd	18,170	4,542	319
	2	cd	15,190	3,797	267
	3	cd	17,000	4,250	299
	4	cd	15,670	3,917	275
	5	kh	18,200	4,550	320
	6	kh	14,070	3,518	247
Set No. 40	1	cd	11,030	2,757	193
	2	cd	14,745	3,686	259
	3	cd	15,000	3,750	263
	4	cd	13,630	3,407	240
	5	kh	14,020	3,505	246
	6	kh	13,220	3,305	232

TABLE VII

Average compressive strength of cement cubes made in fresh water.

No. set.	Total days	Hrs. in electric circuit	Aver. volts	Total amp. hours	Av. comp. str. lb. per sq. in. test cubes	Av. compr. str. kg. cm.^{2} test cubes	Av. compr. str. lbs. per sq. in. control cubes	Av. compr. str. kg. cm.^{2} cont. cubes	% change in compressive strength
1	435	7500	116	35	11494	807	12036	845	— 4.5
2	398	7476	116	35	10863	762	10928	767	— 0.2
3	397	7452	116	35	9114	640	9061	636	+ 0.6
4	370	7452	116	35	8339	585	6760	475	+ 18.7
5	366	7443	116	34	8801	618	8342	585	+ 5.5
6	361	7443	116	34	9686	680	9504	667	+ 1.9
7	360	7442	116	34	9826	690	8719	612	+ 11.7
8	359	7441	116	34	9652	677	10804	758	— 11.2
9	349	7277	116	34	10648	747	11148	784	— 4.5
10	345	7276	116	34	9969	700	9990	701	— 0.2
				Average	9840	691	9729	683	+ 1.2

TABLE VIII

Average compressive strength of concrete cubes made in fresh water.

11	344	7075	116	45	1292	91	1554	109	— 16.8
12	339	7074	116	45	1756	123	1783	125	— 1.5
13	311	5245	116	36	2196	155	2238	157	— 1.9
14	305	5245	116	36	2598	182	2375	166	+ 9.4
15	302	5244	116	36	1541	108	1449	101	+ 6.2
16	301	5243	116	36	2720	191	2781	195	— 2.2
17	299	5225	116	36	3073	216	2865	201	+ 7.2
18	297	5224	116	36	4202	295	3292	231	+ 2.8
19	296	5223	116	36	4488	316	4499	316	— 0.2
20	295	5222	116	36	3089	217	3378	237	— 8.5
				Average	2695	190	2621	184	+ 3.0

TABLE IX

Average compressive strength of cement cubes made in salt water.

No. set.	Total days.	Hrs. in elec. circuit.	Average volts.	Total amp. hours	Av. comp. str. lb. per sq. in. test cubes	Av. compr. str. kg. per cm.^{2} test cubes	Av. compr. str. lb. per sq. in. control cubes	Av. compr. str. kg. per cm.^{2} contr. cubes	% change in compressive strength
21	439	2744	101	80	7955	559	9977	701	—20.2
22	433	2333	91	128	7307	513	9781	687	—25.3
23	435	2760	93	155	6898	484	8872	622	—22.3
24	433	2820	97	132	7172	503	8775	616	—18.5
25	419	2349	92	122	6391	449	9124	640	—29.9
26	418	2703	92	105	8482	595	8565	601	— 1.0
27	414	2711	95	94	8708	612	8097	568	+ 10.7
28	415	2633	93	99	6429	451	8835	620	—27.2
29	412	2613	91	97	9617	675	8635	606	+ 11.4
30	411	2339	95	88	7924	556	8761	615	— 9.5
				Average	7689	540	8943	628	—14.0

TABLE X

Average compressive strength of concrete cubes in salt water.

31	412	2663	91	148	4731	332	4210	296	+ 12.4
32	403	2 64	91	139	4840	340	4899	350	— 2.8
33	403	2665	94	145	4957	348	5090	357	— 2.6
34	403	2642	91	143	3648	256	3344	235	+ 9.1
35	402	2666	94	155	5450	383	4838	340	+ 12.0
36	401	2667	96	146	5557	390	6027	423	— 7.8
37	401	2642	92	145	4692	329	4293	302	+ 9.3
38	400	2639	91	150	3319	233	3441	242	— 3.5
39	398	2674	93	142	4127	290	4034	283	+ 2.3
40	397	2651	91	149	3400	239	3405	239	0.0
				Average	4472	314	4367	306	+ 2.5

chlorine would be the most likely agent. Since the chlorine is liberated at the positive pole it would appear at cube No. 1. In sets No. 22 and No. 23, the cube No. 1 was weakest, but in sets No. 27 and No. 29, cube No. 1 was strongest. Moreover, cube No. 1 in set No. 29 was the strongest in the whole series and hence not likely to have been weakened by the current. The series shows less uniformity in strength than the cubes in either (a), (b) or (c).

Averaging the averages for the four groups, the strength of the cubes Nos. 1, 2, 3 and 4 was only 1.8 per cent less than the control cubes Nos. 5 and 6; and this difference is well within the errors of the experiment.

Summarizing the results we find that for ***the current density covered by the experiments*** the current produces no change in the compressive strength of the cubes. This is in accord with the preliminary observations in the earlier paper (A.I.E.E. Trans. XXX, p. 2067).

Within the limits of current density for which these conclusions apply, it follows that failures in reinforced concrete due to electrolysis are due entirely to the forces produced by increase in volume when the iron is changed into iron oxide and not by any direct action of the electric current upon the strength of the concrete.

DISCUSSION ON "THE COST OF ELECTRICITY AT THE SOURCE" (HOBART), NEW YORK, FEBRUARY 26, 1914. (SEE PROCEEDINGS FOR MARCH, 1914.)

(Subject to final revision for the Transactions.)

J. W. Lieb, Jr: I am sure that under the conditions obtaining in our larger cities the figure given by the author, of $35 per kilowatt of capacity, will not cover the real estate and buildings of a character to satisfy local conditions. The sum of $35, even if otherwise adequate, which I doubt, would allow the merest shell of a building rather than such a structure as it would be necessary to provide to house a plant of the capacity indicated by the author.

H. R. Summerhayes: I ask Mr. Hobart how many days' coal storage is provided for under his plan. In these days of coal strikes and interruptions to transportation it seems necessary to provide a large acreage of land to store a large amount of coal. Such a station ought to require quite a large area for that purpose.

H. W. Buck: There is one advantage which the steam plant has in this comparison. As a rule, the water power plant is many miles from the point at which the power is applied, and the cost of transmission lines, substations, etc., must be added. On the other hand, the steam plant, as a rule, can be located practically at will, and as near as possible to the center of load. This also applies to operating costs on the transmission system, which the steam plant will not have to so great an extent.

Frederick A. Scheffler: I hope that the author of this paper will be more specific in giving us exact data as to how he arrives at $35 per kilowatt for the cost of constructing a complete 100,000-kw. station.

I would like to know what size boiler units he proposes to use, whether he will use steam turbines, and if so, what size units, working steam pressure, superheaters, if any, and degree of superheat, at what rating the boilers will be operated and what kind of stokers will be used, whether under-feed or otherwise, and whether the cost covers economizers.

I have in mind a plant which is being constructed in the West at the present time, of an ultimate capacity of 120,000 kw. The company which is building this plant feels that if it can construct the station, using six 20,000-kw. turbines and twelve 2400-h.p. (nominal rating) boiler units, with superheaters for 200 deg., and operating the boilers at 200 per cent of rating when necessary, and the cost does not exceed $55 per kilowatt complete, it will have a very reasonable and inexpensive station, considering its construction, which is to be of the very best throughout.

H. L. Wallau: I have only one criticism to make of this paper, and that is the figure of $35 per kilowatt. That figure has been qualified in this discussion, and it has been qualified as presented by Mr. Hobart. However, in a city such as Cleveland is, the tendency will be for the engineers of the municipality to say, just as soon as a figure of $35 per kilo-

watt is published in an Institute paper, that it must be pretty close to the actual cost. Apparently the way they figure cost in Cleveland in a municipal undertaking, is to take the figures, for instance, published in the Institute PROCEEDINGS for a 300,000-kw. plant, and say, "If they can do that in a 300,000-kw. plant we ought to be able to do practically that in our 15,000-kw. plant", and as a result they have published a schedule of rates, with a maximum rate of three cents and a minimum rate of one cent. I believe on last Tuesday they got ready to pass a maximum rate ordinance of three cents, to which they expect us to conform. I think for these reasons, when a statement is made, and a figure is published, that it should be carefully qualified, because the tendency towards municipal ownership is growing rapidly in this country, and the analysts are, I believe, making some very grave errors in their calculations.

H. B. Alverson: The load factors given are too high for the usual existing conditions, and while it may not be the intention in the paper to give exact figures, I believe the load factor which will occur in practise will be nearer to 35 or 40 per cent than to 50 per cent. In such cases the cost per kilowatt-hour would rise somewhat higher in proportion than the figures given. Without going into the calculation of the proportion of costs based on the load factor, I think the average experience is that it is very much higher than that which is given in the paper.

O. K. Harlan: Regarding the matter of depreciation, it might be of interest to note that a few weeks ago, before the American Society of Heating and Ventilating Engineers, a paper was presented giving something of the life history of quite a number of the old electric lighting steam-driven plants in this city, and the matter of depreciation was dealt with in that paper. It traces the history of the very earliest installations, including the first steam-driven electric dynamos which were operated in the city. One of the old ones is in the Mills building, and a number of others are down-town, near it. The depreciation was shown to be quite a variable factor; of course, some generators will deteriorate faster than others, and the matter of economy and efficiency is quite an item also; that is to say, some of the more recent generators may be of so much higher efficiency that it is worth while to discard a really good working machine in order to put in a more modern machine of higher efficiency. However, this paper shows that a number of these earlier plants have had a useful life of twenty years; some are really working today, which were installed twenty years ago—but the matter of depreciation, while it is a very interesting subject, is really somewhat intricate, and there are a good many factors entering into the final decision.

H. C. Abell: If Mr. Hobart means the $35 to cover the cost of machinery, water facilities for a plant of that size, storage requirements, working capital, supplies, cost of financing the undertaking, and all the incidental expense, I think unquestionably he used the wrong multiplying factor to arrive at the figure given, which I consider too low.

Another thing which attracts one's attention is the five per cent interest figure used by Mr. Hobart. I do not know of any money source which could be induced to provide funds for a power-generating plant on a five per cent basis.

I suppose amortization placed at 4.6 per cent is a depreciation fund, for a power plant is usually not amortized, but is a continuous business where the owners have to provide funds continuously for new construction after the plant once starts. Amortization is entirely different from depreciation; the two terms should not be confounded.

A. H. Kruesi: With regard to depreciation, I believe obsolescence often cuts a much larger figure than depreciation due to wear and tear. I am associated with a large steam-turbine power plant built eleven years ago. The stokers and their auxiliary equipment are now being scrapped because they are obsolete, though not worn-out. A number of boilers installed seven years ago are also being scrapped because they are of a type no longer manufactured and the allowable working pressure has been reduced, so that they have become unsuitable to their purpose. The entire switching equipment is being replaced after eleven years' use because the plant has grown and it is no longer adequate for the amount of power behind it. I agree with the criticism of Mr. Hobart's paper, on the score of his capital cost charges. I do not see how they could possibly be figured at less than 15 per cent.

V. Karapetoff: Mr. Hobart's paper has been criticised on account of the specific numerical data given in it. I know from certain experiences in court testimony that outsiders are only too liable to ascribe to the Institute any data published in its PROCEEDINGS, in spite of the well-known fact that the Institute is not responsible for opinions expressed by its individual members. To me, personally, Mr. Hobart's paper is exceedingly interesting and instructive in giving a concrete method of calculation. If he had chosen to use letters, instead of numerical values, I am afraid the paper would be exceedingly difficult to follow, but then it would have been of greater general interest, as any one could substitute numerical values for his particular problem and the above criticism would be obviated.

I was surprised at the statement that the outlay for the turbo-generators, cables, exciters, switch gear, etc., amounts to only 30 per cent of the total cost of the generating station. It seems to me that engineers in this country ought to be more interested in the Thury system of generation, which, so far, has been mainly applied to hydroelectric stations, but lately was chosen in London for underground distribution from a steam plant. The principal advantage of the Thury system is that not only the cables themselves cost much less, but also the generating station is lower in cost; while the generators themselves are more expensive, the cost of auxiliary apparatus is much lower. If one goes into a station like the Northwestern station in Chicago, it is the auxil-

iaries which strike one's eye, and it is the auxiliaries which occupy the most room and apparently seem to cost the most.

G. L. Knight (by letter): The author of this paper states that a 100,000-kw. steam station, consisting of five 20,000-kw., 60-cycle, 1800-rev. per min., three-phase turbo-generators, together with all the apparatus, both steam and electric, required for the operation of such a plant, can be built in this country for an over-all charge of $35 per kilowatt.

This paper, being presented before the A. I. E. E., presupposes in the absence of contrary statement that the figures given represent American practise, but in replying to the discussion on his paper in the meeting of February 26, Mr. Hobart defended his estimate by the following figures taken from estimates of plants constructed in England:

Turbo-generators, including exciters and switch gear	$10.50 per kw.
Steam raising plant	8.50 " "
Condensing equipment	5.00 " "
Building	8.00 " "
	$32.00 per kw.

This leaves only $3.00 for the rest of the charges, which must include land, general engineering and construction expense other than that included in the items as given, also all overhead charges during the construction period.

In place of the figures set down by Mr. Hobart, I would give the following as minimum values, and while they will vary greatly according to the conditions a plant must meet, the total cost per kilowatt will be often much nearer $75.00 than the figure given.

Building		$10.00	
Turbo-generators, including exciters.	$12.50		
Switch gear	3.00		
		15.50	
Steam plant			
Boilers	6.00		
Stokers	2.50		
Flues and piping	2.00		
Coal and ash handling equipment	1.50		
		12.00	
Condensing equipment			
Condensers and pumps	3.00		
Condensing tunnels	2.00		
		5.00	
			42.50
Engineering, drawings, supervision and other overhead expenses, 15 per cent			6.35
Allowance for piecemeal construction and contingencies, 15 per cent			6.35
			$55.20

To those of us in the employ of public service companies this paper seems at least ill-advised. Regulating bodies and the advocates of municipal ownership are constantly challenging our capital costs, and when a company's books show a cost of $50 to $75 per kilowatt for a new plant (and older ones will be even higher), papers such as this are quoted in attempts to prove such costs excessive.

In such cases it is assumed, by those who do not know the Institute rule, that having accepted such a paper for presentation at a meeting, the Institute must have passed on it as being reasonable.

I think Mr. Hobart should have stated that his whole case rested on English figures, and I am inclined to believe that even in England no plant has ever been completed which, when all charges were accounted for, came within his figure at $35 per kilowatt.

Frederick G. Strong (by letter): Permit me to say a word in behalf of our water powers; they seem to have very few friends among those who have discussed Mr. Hobart's paper.

I remember a paper by Dr. Emory, in which the general statement was made that where the cost of water power development exceeded $150 per horse power a steam-driven plant would be advisable where good coal could be obtained at about $4 per ton. We have heard, periodically, that a slight increase in efficiency or a slight decrease in the cost of steam-driven machinery, would cause the water powers to be abandoned, or left undeveloped.

We have seen a marked increase in steam efficiency in the past ten years and a marked decrease in cost per kilowatt, due to increased size of units and increased speed and activity of material, but the water powers are still in use. None have been abandoned, and plans are being formulated for the development of many more.

The theory that water powers should be abandoned, or left undeveloped when they show a greater cost than equivalent steam-driven stations, does not seem correct, and I believe the time is not far distant when we will develop every available water power, to the end that the coal supply may be conserved as much as possible.

Undoubtedly the water powers at Holyoke, and Lowell, and Lawrence, and Manchester have cost far more than equivalent steam power, but if those investments were annihilated, does any one believe that the power would be left undeveloped?

In the energy of falling water Nature has not by any means given us something for nothing, but it is doubtful if we may expect a nearer approach.

H. M. Hobart (by letter): I shall deal with the contributions to the discussion of my paper in the order in which they were made.

As to the first comments which were made by Mr. Lieb, it

would appear that his intention is to supplement my paper and emphasize the importance that it should not be construed as applying to stations located in or near large cities. It was clearly shown in my paper that I referred to a station located with especial reference to low cost of land, abundance of circulating water and low price for fuel. This necessarily locates the station at some situation where architectural effect is absolutely out of place. In the recent report made to the London County Council by Messrs. Merz and McLellan, it is pointed out that in modern plants "the power house tends more and more to become a metal structure for housing the machinery rather than an actual building in the usual sense." The savings which can be effected under the conditions which I describe for my plant are inapplicable to a power house located in our larger cities, and I am glad that Mr. Lieb took the occasion to emphasize this point. Furthermore, in city plants supplying electricity for all sorts of purposes to a large community there must be large investments for duplicate switch equipments and for supplying large numbers of feeders. This inevitably runs up the cost, as it does also the need for economizers, which are justifiable under these circumstances, since the price of fuel is relatively high. It was expressly stated in my paper that no outlay for transformers was included, and further, that the estimates related to 60-cycle generating sets. These sets were only five in number, of the most modern type, and were for a rated speed of 1800 rev. per min. In city stations it is often necessary to supply, not only 60-cycle electricity, but also 25-cycle electricity, and furthermore, the stations will usually be found to be equipped with more than one size of generator. Moreover, the average rating of all the generators in the station is usually much below that of the 20,000-kv-a. units on which I based my estimates, and they are driven at lower speeds, as a consequence of which they are larger, more expensive in first cost, more wasteful of fuel, and a greater outlay is required for the attendance upon them. When a given aggregate output is delivered from ten small units, as against five large units, the outlay for wages in the station is decidedly greater. Mr. Lieb considers that the real estate and buildings for a station in our larger cities would not be covered by $35 per kilowatt of capacity. Taking it at $40, and including an appropriate allowance for the increased outlay for switch gear and for economizers and transformers, then, with an allowance for engineering and contingencies amounting to 10 per cent of the total, we arrive at over twice the capital outlay per kilowatt installed that would have been necessary on the same scale of prices for a station complying with the conditions set forth in my paper.

In the matter of Mr. Summerhayes's suggestion that in these days of coal strikes and interruptions to transportation, it seems necessary to provide a large acreage of land to store a large amount of coal, I would point out that with such locations as that clearly contemplated in my paper, the land could not rea-

sonably be taken as costing more than $200 per acre. On this basis, the outlay for a site of 50 acres would only amount to $10,000, which is less than three-tenths of one per cent of the total capital outlay for this 100,000-kw. generating station. Mr. Summerhayes evidently also had in mind the conditions in large cities, far away from the mines, and I quite agree with him that under these conditions the point which he mentions would be one requiring careful attention.

I fully agree with the point which Mr. Buck makes that the steam plant has the advantage over the waterpower plant, that it may sometimes be located quite near to the center of the load, thus minimizing the costs in transmitting the electricity to the customers. However, I dealt with "The Cost of Electricity *at the Source*" and pointed out that by locating a generating station where the conditions as regards fuel and water supply and cost of land are favorable, electricity can be manufactured for a low price and that industries, the cost of whose product depends largely on the outlay for electricity, would be well advised to realize and take advantage of such possibilities.

I am pleased to be able to comply with Mr. Scheffler's request more specific data as to how I arrive at the cost of the complete 100,000-kw. station. This is set forth in the following table:

	Five 20,000-kw. units
I—Turbo-generators, exciters, cables and switch gear, but exclusive of step-up transformers	$10.50
II—Boilers, superheaters, furnaces, and stokers, but exclusive of economizers, pumps and piping	9.00
III—Condensers, exclusive of pumps, piping and tunnels	2.50
IV—Pumps, piping, tunnels, valves and traps	1.50
V—Land and all buildings and structures, including machinery foundations, stacks, bunkers and conveyers	8.00
VI—Engineering and contingencies (10 per cent)	3.50
Total cost per kilowatt	$35.00

Mr. Wallau also points out how important it is that the conditions under which such figures can be reached should be clearly stated. I welcome Mr. Wallau's assistance in helping me to point out the distinction between plants of the size and character which I am discussing in the paper, and such relatively small plants as those to which he refers.

Regarding Mr. Alverson's comments, I show in the curves in Fig. 2, on page 396, the cost of electricity for all load factors down to 0.30. It may, however, be of interest to point out that the application of electricity to chemical and certain other industries often permits of much higher load factors than have, until recently, been at all customary, and that decided commercial importance attaches to a knowledge of the costs under such conditions of high load factor. Such applications are usually only practicable when the cost of electricity is very low, and in the

near future we shall certainly see such industries purposely located where conditions are favorable as regards plentifulness of water and low cost of fuel and land.

Mr. Harlan makes some interesting suggestions. He calls attention to 20 years as a reasonable life for electrical machinery in many cases. My figures for the investment cost are based on an equivalent life of 15 years.

The next two contributors to the discussion of my paper were Messrs. Abell and Kruesi. It is the opinion of both of these gentlemen that my investment costs are a little too low, Mr. Abell's criticism being that funds can rarely be obtained for a power generating plant at so low a rate of interest as five per cent, and Mr. Kruesi emphasizing the importance of the obsolescence factor. All engineers realize the difficulty of equitably assessing the investment costs, owing to the impossibility of predetermining the obsolescence factor and the great difference in the financial standing of companies embarking upon electricity supply enterprises. I believe that the figures on which I have based the annual investment charges are representative for the case under discussion, but it is obviously important to apply a safety factor which should be inversely proportional to the financial standing of the companies.

I am interested in Prof. Karapetoff's suggestion that my paper would have been of greater general interest had I chosen to employ letters instead of numerical values. My own experience is, however, that the paper would not have attracted attention. It is my experience that papers rarely fulfil any useful mission unless they stimulate discussion.

Mr. Knight puts forward an interesting alternative estimate, regarding which I should like to offer the following comments. For "turbo-generators, including exciters," Mr. Knight allows \$12.50 per kilowatt. For "turbo-generators, exciters, cables, and switch gear" I gave the figure of \$10.50 per kilowatt. For a city station with its more elaborate provision for switch gear and its large number of feeders, the equivalent allowance would be \$11.50 per kilowatt were five 20,000-kw., 60-cycle, 1800-rev. per min., unity power factor turbo-generators to constitute the equipment. If we turn to page 981 of Messrs. Stott, Pigott and Gorsuch's paper entitled *Present Status of Prime Movers* and published in the A.I.E.E. PROCEEDINGS for June, 1914, we find \$7.50 per kilowatt taken as the "average" cost of a 20,000-kw., 60-cycle, 1800-rev. per min. turbo-generator. This would seem to indicate that my figures are conservative for large plants favorably located.

As regards the other items, Mr. Knight's estimates do not differ materially from my own, except that he allows 30 per cent for "engineering, drawings, supervision and other overhead expenses, piece-meal construction and contingencies" as against my allowance of 10 per cent for "engineering and contingencies." I quite agree that such items may run up to large values and that for each case they must be separately considered.

The last contribution to the discussion is by Mr. Strong and is to the effect that waterpower should—and will—be developed irrespective of the relative capital and operating costs of the investment, as compared with the equivalent undertaking employing turbo-driven generators. One of the objects which I had in view in writing my paper was to call attention to the liability of misapplication of capital. Large amounts are often invested in waterpower developments running much above $100 per kilowatt installed and in some of these cases it could be demonstrated that the greater capital charges more than offset the elimination of fuel costs. Often a steam-turbine station at a favorable site would represent a better investment. But there is the liability that any consideration of a steam-turbine station will be dismissed after very superficial calculations, in the mistaken belief that the investment for the steam station will necessarily be excessive. Fifteen years ago (before the advent of the steam turbine) the case was much more favorable for waterpower as compared with steam.

It is equally desirable to call attention to the related danger that the high efficiency of the internal combustion engine will attract capital, notwithstanding that the generating sets alone will cost at least $60 per kilowatt and even the fuel cost will be as great with the internal-combustion engine as with the steam turbine with oil at 2 ½ cents per gallon and coal at $3.00 per ton.* The outlay for attendance, lubrication, and repairs will be much greater with the internal combustion installation. The misdirection of capital in this way would be checked by the more general realization of the low investment cost associated with steam turbines.

In conclusion I should like to take the opportunity to discuss briefly the factors which have contributed to the rapid progress which has been made toward decreased cost of electricity. There has been of recent years rapid progress in the direction of increased efficiency of prime movers. This has been accelerated by the use of individual sets of very large capacity. Not only have these sets relatively high efficiencies, but the investment cost per kilowatt is relatively low. It is well known that the steam consumption of modern steam tubines is much less than ten years ago, consequently a given capacity of steam raising and condensing plant will now provide steam for a station of much greater capacity than formerly. The methods of firing steam boilers have simultaneously undergone radical changes, so that in addition to the lower investment cost, due to the decreased total capacity of steam raising plant required, there is the further investment gain due to the more intense utilization of the plant. In view of these considerations, there will be no difficulty in realizing that a given outlay for buildings and machinery will

*This is explained in my paper entitled "The Cost of Manufacturing Electricity", page 617 of the *General Electric Review* for September, 1913.

be adequate for delivering much more electricity per annum than formerly.

At the same time it must be recognized that in and near large cities there has been a counteracting tendency to require much finer buildings with much greater attention to architectural effect, and since, as Mr. Lieb has pointed out, the cost of land and buildings may easily be the largest item for such undertakings, any lower investment cost per kilowatt for machinery permits of a much less percentage decrease in the total cost than is obtained in the case of such plants as those to which my paper had specific reference. My paper dealt exclusively with plants of enormous capacity (in this case 100,000 kw.) located under such conditions that the outlay for machinery constitutes much the largest item. Under such circumstances the contrast between a modern plant equipped with machinery purchased at modern prices and the best plant which could be put down ten years ago and which would be of much smaller total capacity, owing to the then relatively small demand for electricity, is marked.

It should, in conclusion, again be emphasized strongly that my estimates do not apply to plants located in or near large cities. On the first page of my paper I called attention to "the great field for electricity for large manufacturing enterprises which can be located near the source of electricity supply." I expressly stated that my costs applied to the manufacture of electricity "in bulk" and "under favorable conditions" and I was very precise in pointing out that my costs did not apply to electricity manufactured in and near large cities.

DISCUSSION ON "SOLENOIDS" (UNDERHILL), WASHINGTON, D. C., APRIL 24, 1914. (SEE PROCEEDINGS FOR APRIL, 1914.)

(Subject to final revision for the Transactions.)

Charles W. Burrows: I would like to call attention to a few points in which I am not in complete agreement with the author.

In the first place, Tables I to IV used in the calculation of the magnetic field are given out to the sixth place of decimals. As the assumptions made in the computations did not seem to warrant such precision I recalculated some of the results by a more precise formula, as follows:

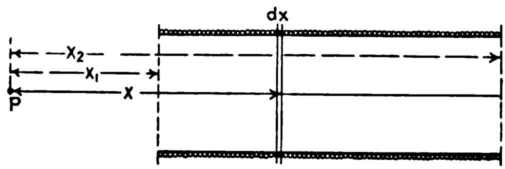


FIG. 1

The magnetic field at any point on the axis of a solenoid is given by the equation

$$H = 0.2\,\pi\,n\,I \int \frac{r^2}{(r^2 + x^2)^{3/2}}\,dx \tag{1}$$

where

H = magnetizing force of solenoid
n = number of turns per cm.
x = axial distance of element of coil
r = radius of coil
I = current in amperes in coil.

The integration of equation (1) gives

$$H = 0.2\,\pi\,n\,I \left[\frac{x}{\sqrt{r^2 + x^2}}\right]_{x_1}^{x_2}$$

$$= 0.2\,\pi\,n\,I \left[\frac{x_2}{\sqrt{r^2+x_2^2}} - \frac{x_1}{\sqrt{r^2+x_1^2}}\right] \tag{2}$$

where x_1 and x_2 (Fig. 1) are the distances from the point where H is measured to the two bounding planes of the solenoid.

If we measure x in terms of r and let

$$\alpha_1 = \frac{x_1}{r} \text{ and } \alpha_2 = \frac{x_2}{r}, \text{ then}$$

$$H = 0.2\,\pi\,n\,I \left(\frac{\alpha_2}{\sqrt{1 + \alpha_2^2}} - \frac{\alpha_1}{\sqrt{1 + \alpha_1^2}}\right) \tag{3}$$

The quantity in ( ) is a more exact expression for what is called h in the paper.

$$h = \left(\frac{\alpha_2}{\sqrt{1+\alpha_2^2}} - \frac{\alpha_1}{\sqrt{1+\alpha_1^2}}\right) \tag{4}$$

At the center of a coil one radius long

$$\alpha_2 = +\frac{1}{2}$$

$$\alpha_1 = -\frac{1}{2}$$

$$h = \left(\frac{\frac{1}{2}}{\sqrt{1+\left(\frac{1}{2}\right)^2}} - \frac{-\frac{1}{2}}{\sqrt{1+\left(\frac{1}{2}\right)^2}}\right)$$

$$= \frac{2}{\sqrt{5}} = 0.894$$

and not unity as given in the table.

For an adjoining similar solenoid

$$\alpha_1 = \frac{1}{2}$$

$$\alpha_2 = \frac{3}{2}$$

$$h = \left(\frac{\frac{3}{2}}{\sqrt{1+\left(\frac{3}{2}\right)^2}} - \frac{\frac{1}{2}}{\sqrt{1+\left(\frac{1}{2}\right)^2}}\right)$$

$$= \frac{3}{\sqrt{13}} - \frac{1}{\sqrt{5}} = 0.385$$

and not 0.363560 as given in the table.

Consequently in Table I, page 601, the column headed h_a should be corrected as follows:

m_5	h_a as given	h_a as corrected
1	0.353560	0.385
2	0.089443	0.096
etc.	etc.	etc.

These errors are transferred to Table II on page 602, where column 1 should be corrected as follows:

Column 1 as given	Column 1 corrected
1.0000000	0.894
1.353560	1.279
1.443003	1.376

The most accurate figure in this table is in column 6, where the number 1.992872 should be replaced by the true value 1.968.

All these errors are due to the assumption that the formula for the field at the center of a single turn holds for a layer whose length is equal to the radius. The errors may be eliminated or reduced by taking as elements shorter lengths, as Mr. Underhill has done in his book on "Solenoids," or individual turns, as Thomson has done.

Even though suitable accuracy is obtained in this way, I do not believe the method is valuable, since the desired results can be obtained more simply otherwise.

Instead of calculating the force due to each individual element of a solenoid we may approach the matter from a somewhat different point of view.

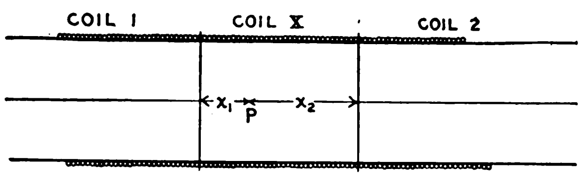


FIG. 2

Any finite solenoid as coil X (Fig. 2) may be considered as having been made from an infinite solenoid by removing the two infinite portions represented by coil 1 and coil 2. The magnetic field within the solenoid X at a point P on the axis, distant from its bounding planes by x_1 and x_2, respectively, is then equal to the field due to the original infinite solenoid minus the fields produced at the point P by the coils 1 and 2. The field due to coil 2 is given from equation (3) by making $\alpha_2 = \infty$.
Then

$$H_2 = 0.2\,\pi\,n\,I\left(1 - \frac{\alpha_1}{\sqrt{1+\alpha_1^2}}\right) = 0.2\,\pi\,n\,I\,h_2$$

Similarly the field due to coil 1 is

$$H_1 = 0.2\,\pi\,n\,I\left(1 - \frac{\alpha_2}{\sqrt{1+\alpha_2^2}}\right) = 0.2\,\pi\,n\,I\,h_1$$

where α_1 and α_2 are the distances in terms of the radius of the point P beyond the free ends of the coils 2 and 1 respectively.

For the original infinite solenoid

$$H = 0.2\,\pi\,n\,I \times 2$$

so that for the finite coil (X),

$$H = 0.2\,\pi\,n\,I\,(2 - h_1 - h_2)$$

h_1 and h_2 may be called the end corrections and are tabulated in Table I and shown in Fig. 3.

To use this table let us calculate the field at a point on the axis of a coil ten radii long at a point two radii distant from one end. From the table,

$$\begin{aligned} h_2 &= 0.1056 \\ h_8 &= \underline{0.0080} \\ h_2 + h_8 &= 0.1136 \\ 2 - 0.1136 &= 1.8864 \end{aligned}$$

so that

$$H = 0.2\,\pi\,n\,I \times 1.8864$$

TABLE I

Showing the end effects of a solenoid, where h_1 and h_2 refer to the corrections for the two ends of the solenoid.

0.0	1.0000
0.1	0.9005
0.2	0.8039
0.3	0.7126
0.4	0.6286
0.5	0.5527
0.6	0.4855
0.7	0.4266
0.8	0.3755
0.9	0.3310
1.0	0.2928
1.5	0.1681
2.	0.1056
3.	0.0511
4.	0.0300
5.	0.0195
6.	0.0136
7.	0.0102
8.	0.0080
9.	0.0064
10.	0.0050

The data of this table are plotted in Fig. 3.

On page 605 we find "* * * * * conceiving the m.m.f. as consisting of two components, one of which produces the magnetizing force to magnetize the plunger while the other component produces the magnetizing force to coact with the flux in the plunger and thus cause attraction."

Instead of considering that the plunger is fully magnetized and the m.m.f. is divided into two portions, one of which magnetizes but does not attract and the other of which attracts but does not magnetize, I look at the matter somewhat differently.

I consider that the entire m.m.f. is used to magnetize the plunger and that the entire m.m.f. is also used to react on the magnetized plunger. To be sure, the magnetic induction produced is not the greatest possible for the given m.m.f. because of the relative positions of the solenoid and plunger, and also because of the self-demagnetizing influence which has been neglected entirely.

The formula (**35**) on page 607 is not strictly correct. This is evident when we consider the special case of the bar located symmetrically within the solenoid. According to the formula the pull in this position should be a maximum. However, we know from experimental evidence that the pull is zero. It would be better to say that the pull is proportional to the product of the field strength and the leakage from the bar. This is equivalent

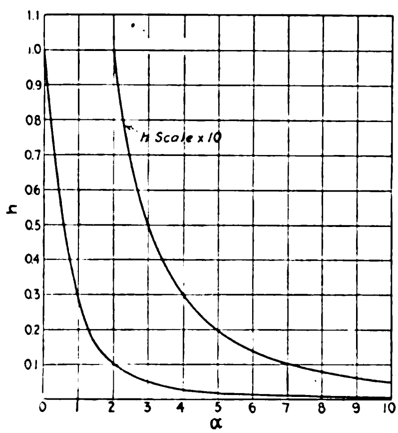


FIG. 3—CURVE SHOWING THE VARIATION OF α AND h.

to saying that the pull is due to the reaction between the magnetic field and the free poles.

Fig. 26, page 611, presents some anomalies. When the plunger is inserted almost to the far end of the solenoid the figure shows that 10,000 ampere-turns give rise to a greater induction than 40,000. As it is obviously impossible that the larger m.m.f. should give rise to the smaller induction, the premises on which these data were calculated must be in error. Equation (**37**), page 610, used in the calculations of the data for these curves, is open to the same objections as those brought against equation (**35**). The error due to assuming that this equation holds, may be enough to account for the discrepancy.

E. R. Carichoff: In his reference to my paper published in 1894, what Mr. Underhill mentions is only a corollary to my proposition, and this corollary is true only when μ is supposed to be constant. My proposition deals with certain definite assumptions, one of which is only approximately true—viz., the assumption of no leakage.

I will give here substantially the discussion—Having given a magnet of definite length and cross-section, an air gap of given length, and any constant magnetomotive force, to find the polar area that will give a maximum force.

In the formulas, A, L, B and H, represent respectively the area, length, induction and magnetic force for the air gap, and a, l, b and h the same quantities for the iron, the flux in the air gap and in the iron being assumed to be the same.

$$P \propto A B^2 \propto A H^2 \tag{1}$$

$$\frac{dP}{dA} = 2 A H \frac{dH}{dA} + H^2 = 0$$

for maximum force, or

$$2 A \frac{dH}{dA} + H = 0 \tag{2}$$

The condition of constant m.m.f. is

$$HL + hl = \text{constant.} \tag{3}$$

The condition of no leakage is

$$AH = a\, b \tag{4}$$

By differentiating (3) and (4) with respect to A and substituting in (2) we have the relation

$$\frac{a\, db}{l\, dh} = \frac{A}{L} \tag{5}$$

This means that the tangent to the curve representing the permeance of the iron equals the permeance of the air gap; and further, if μ is constant it means reluctance of iron = reluctance of air gap.

Again, if the polar area is constant and the length of the air-gap is made a variable, the other conditions remaining as before, and the problem is to find the length of air gap that will make the product of force times length of air gap a maximum, we have

$$W \propto A B^2 L = A H^2 L \tag{6}$$

and

$$\frac{dW}{dL} \propto 2 LH \frac{dH}{dL} + H^2 = 0$$

maximum work, or

$$2 L \frac{dH}{dL} + H = 0 \tag{7}$$

By differentiating (3) and (4) with respect to L and substituting in (7) we get the same relation given in equation (5).

Mr. Frank Fowle has described certain investigations made by him on telegraphic relays which resulted in securing greater force by means of enlarged poles, but I believe that, generally, designers have not given sufficient attention to this point.

There is another relation that I have found most useful, and that is—what diameter of core should be used to get maximum force when the air gap is inside the coil and the outside diameter of the coil is fixed and the heating in the coil is a constant.

Oliver Heaviside, in his "Electrical Papers," Chapter XVII, page 103, gives the relative diameters of core and coil as

$$\frac{y}{x} = \frac{\sqrt{5} - 1}{2} \tag{8}$$

where y is the diameter of the core and x is the outside diameter of the wire winding, but not including the outside wrapping.

In this equation no allowance is made for space between the winding and the core. My practise is to allow 0.2 inch on each side of the core. With this constant inserted, the equation becomes

$$x = \frac{1}{2}\, y + \sqrt{(y + 0.4)^2 + \left(\frac{1}{2}\, y\right)^2} \tag{9}$$

As an approximation correct within a small percentage I use the following:

$$\frac{x - 0.4}{y} = 1.6 \tag{10}$$

It is interesting to note that values of 3.6 for x and 2 for y satisfy both equations (**9**) and (**10**).

In these equations μ is supposed to be constant.

C. R. Underhill (by letter): The method described by Dr. Burrows for finding the magnetizing force along the axis of a solenoid is simple and very interesting. It is stated on page 597 of the paper that the calculated values are only approximate. Therefore, a comparison of the values obtained by Dr. Burrows's method and those obtained by the approximate method of the author will be of interest. In the following table are shown the ratios which are obtained by dividing the author's values in Table II of the paper by those calculated by the method of Dr. Burrows.

Section of reference a / m	1	2	3	4	5	6	
1	1.12						
2	1.06						
3	1.05	1.025	(middle section)				
4	1.05	1.02					
5	1.05	1.02	1.017	(middle section)			
6	1.045	1.02	1.015				
7	1.045	1.02	1.015	1.012	(middle section)		
8	1.045	1.02	1.015	1.012			
9	1.045	1.02	1.015	1.012	1.011	(middle section)	
10	1.045	1.019	1.015	1.011	1.011		
11	1.044	1.017	1.013	1.011	1.011	1.01	(middle section)

Anyone wishing to work closer than one or two per cent should, therefore, calculate the values by Dr. Burrows's method. Those engaged in practical design can use the data directly from the curves in Figs. 15 to 24, because it is impossible, with the present known methods, to predetermine the pull between a solenoid and plunger at all points in its travel, with a greater accuracy than several per cent. The values for the end sections are of little importance because a long-range solenoid usually consists of more than two sections.

As to the demagnetizing action of a solenoid on its plunger, this is briefly touched upon at the bottom of page 594 and again on page 615 of the paper. For all practical purposes, the core or plunger can be assumed to be very long, and the demagnetizing action ignored for ordinary flux densities. The demagnetizing effect is only noticeable when uneconomical magnetizing forces are used. Fig. 25, page 610, shows this. The plunger was thoroughly saturated with 10,000 ampere-turns, and at this value the demagnetizing effect is scarcely noticeable. Even with 20,000 ampere-turns it is not serious. As the magnetizing force is increased, the plunger is saturated for greater portions of its length, so that when abnormal magnetizing forces are used the effect is noticeable.

The author's reference to the important law of Mr. Carichoff, which is based on the assumption of no leakage, was given to emphasize the importance of magnetic leakage in all electromagnets of the plunger type, since the leakage increases the flux in the plunger and, consequently, the pull. In electromagnets of the horseshoe type and modifications of the same, the pull due to magnetic leakage is lost because the relative positions of the coils and cores are unfavorable and, furthermore, they are usually fastened together.

The characteristics of alternating-current electromagnets are easily explained when magnetic leakage is considered. Many otherwise excellent papers and articles have been written upon the subject of electromagnets, but, in nearly all cases, no leakage is assumed: consequently, their value is lessened.

The characteristics are best predetermined from the standpoint of energy, but, until the permeances of the leakage paths for different positions of the plunger are thoroughly worked out, only the average mechanical force or pull can be calculated, and this is of little use to designers of electromagnets, excepting in the design of electromagnetic hammers and the like; it does not throw light on the mechanical forces or pulls at all points throughout the entire range of travel of the plunger, and the latter is usually very important.

DISCUSSION ON "SOME INVESTIGATIONS ON LIGHTNING PROTECTION FOR BUILDINGS" (DEBLOIS), WASHINGTON, D. C., APRIL 24, 1914. (SEE PROCEEDINGS FOR APRIL, 1914.)

(Subject to final revision for the Transactions.)

E. E. F. Creighton: There has been very little work done on the direct study of cloud lightning, and therefore this paper may be considered as a turning point. There is no committee at the present time of the American Institute of Electrical Engineers or of the National Electric Light Association which will give this subject the study that is needed. Perhaps the problem is important enough to receive the attention of the Bureau of Standards, and it would be an excellent one for that bureau to take up. It requires not only an organization of trained laboratory men, but also men who can develop instruments as they are required by the conditions that become apparent.

One very important point that has been discussed many times is the natural frequency of the lightning stroke. A great many of the great scientists of the world have discussed it—I think Professor Thomson has given a number of discussions on it, and also Dr. Steinmetz, and the matter is still held in abeyance. I do not think that the work done with the oscillograph can prove either that the frequencies are high or are low, because the oscillograph will not respond to these high frequencies, although it will respond to the summation of them. I have obtained instances of summation in the laboratory with five million cycles per second. This discharge through the oscillograph gives a deflection. Of course, what was produced in the oscillograph was the summation of the oscillations, giving the resultant quantity of electricity that had passed through the bifilar vibrator. Theoretically, I think there is in some cases a high frequency, and practically, types of lightning arresters which are sensitive to high frequencies and not very sensitive to impulses, respond by discharging, showing that there is at times a high frequency in the lightning.

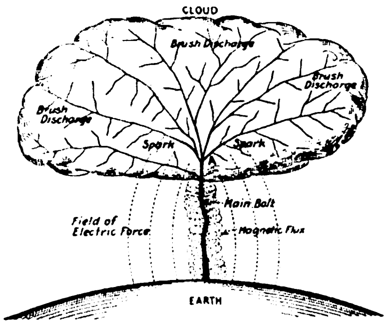


FIG. 1

Theoretical analysis of the cloud conditions, will, perhaps, illustrate what part of the discharge can oscillate and what part of the discharge cannot. Assuming that the electricity is freed at different points in the cloud, as shown in Fig. 1 herewith, there will be a brush discharge from different parts of the cloud toward one centralized point A that is failing, and as it approaches that centralized point there will be formed vapors of sufficient in-

tensity to be called spark discharge. Up in the outermost parts of the cloud the electricity is drawn through high resistance, and all the laboratory experiments show that this resistance is above the critical value which will allow oscillations. The conditions of high resistance exist even in those parts where the blue brush discharge is just turned to a definite bright spark discharge. But somewhere just above the point A, around the upper part of the main bolt of lightning, the resistance becomes very low. From this region down to earth there is a good conductor to transmit current, which is surrounded by magnetic energy, indicated in the sketch by rings around the main bolt. There is also a high voltage from end to end of the main bolt which gives electrostatic energy. These three conditions, electromagnetic energy, electrostatic energy and low resistance, will naturally produce an oscillation. Therefore I think there is an oscillation in the main part of the discharge path, but the discharge in the rest of the cloud could not possibly oscillate.

George R. Olshausen: I congratulate Mr. DeBlois on being successful in getting any registrations whatever with the oscillograph in the short period of time of twenty minutes in which this work was done. You must remember that we do not know when the lightning is coming, where it is coming, and when you bear in mind that we only have twenty minutes in the whole season to work in, I think it is very remarkable that Mr. DeBlois secured any results at all. He seems to think that these registrations cannot be the so-called related charges. Professor B. Walter, of Hamburg, first took pictures by means of a moving camera, and showed that, in general, the lightning stroke consists of a great number of parts, showing that there is a so-called predischarge which breaks down the air, first going part of the way, and then proceeding a little further, and finally a complete flash is made. This first flash usually heats up the air and makes it more conducting than before. After the first discharge there is usually a period of rest, and then there may be a gradual leaking of electricity along this heated part, which might make a continuous current for quite a long time, and then there may be a series of intervals and discharges, and finally there may be a closing flash something like the residual discharge of the condenser.

As to the period of the discharge, something can be said in both directions, that is, for the unidirectional discharge and also for the associated discharge. The experiments made by Pockels in determining the current of a stroke of lightning, by means of the magnetizing effect on prisms obtained from the mineral base salt, seemed to indicate that the flash is unidirectional, and occasionally that they were not magnetized at all, and in that case we may have been dealing with an oscillatory flash. Ende (*Electrotechnische Zeitschrift*) has made some calculations by means of the Maxwell equations on the frequency of a flash, and he comes to the conclusion that its probable frequency is some-

thing like 8000 oscillations per second. However, a great many assumptions are made in this calculation. One assumption, for instance, is in regard to the self-induction of such a flash. What is the self-induction of a circuit which is not closed? Hertz says there is no such thing as self-induction of a straight rod. Our ideas of self-induction, when applied to closed circuits, are not very well defined.

A. G. Webster: As to the conclusions in the paper, I agree with what has been said by the two preceding speakers. There is no doubt that Fig. 2 shows an oscillation there, but it has not been proved that there are any high-frequency oscillations. Whether there are any such, I do not know, and I do not suppose anybody else does, although Professor Thomson, in talking with me recently, admitted that he did not believe there were any high-frequency oscillations.

All that Dr. Olshausen said about the complication of the phenomenon is absolutely true. As Dr. Olshausen has said of self-inductance, I believe there is self-inductance here. But what is it? It is much worse to calculate than the reluctance of a solenoid. Everybody knows that, who has examined, experimentally, sparks in revolving mirrors. I have examined them for a good many years, and I believe, perhaps, I was the first to show the oscillatory character of such discharges in a lecture which I delivered in the Lowell Institute at Boston seventeen years ago. There is always at the start of the discharge something that does not come as regularly as the rest, that is, there is a breaking away which heats the air, ionizes it, and after that comes the regular flashes—these come pretty regularly after that.

In this connection I think of a commonplace phenomenon which Professor Thomson will corroborate or disprove, because there is no one who makes more daily observations from just looking out and looking around than he does. I believe that it is very common for barns with hay in them to be struck by lightning, and I suppose the reason is that there is somewhere an upward current of hot air. As has been said, these lightning strokes have been blown about. In Fig. 2 of the paper, in the upper part of the photograph you see the discharge is not straight and in the lower part it has apparently been blown about very violently. We have been told to look out for current when it strikes. You cannot tell when a lightning stroke is coming, and you cannot dodge a lightning stroke. There are places where hot currents of air seem to make good paths for the lightning. Whether the heat resistance is above or below, it is hard to tell. If it is above, it will not be oscillatory. You engineers know what the resistance of a long arc is, and I am pretty sure that when the arc is gone, the resistance goes down very much, indeed.

As has been said, the whole thing is a good deal like a Hertzian oscillator, only the cloud is spread out some times for miles, and as you watch it you do not get as good observation as in revolving

machinery, but you get something. What Dr. Olshausen has said is true, it breaks away all over, and whether that is hard to see clearly or not, I do not know.

As I said, this photograph shows an oscillation. There is one thing which is evident, if there had been a different potential between the cloud and earth, or the free cloud, there would not be a lightning stroke. There must be a condenser, and in order to have a stroke it might empty itself out. You speak of the residual discharge in a Leyden jar, but you seldom find discharge going up the other way. The oscillograph will certainly show a current, if it does not burn out, or if something else does not happen to it.

Elihu Thomson: The results Mr. DeBlois has shown are, in a large measure, explanatory of what has been my impression for years, in fact, as long as I can remember having any thought or dealings with lightning or lightning protection. While it may be true that within the path of the discharge there may be oscillatory portions, yet I think the main phenomenon is that of a continuous current.

I arrived at that conclusion early in my investigations in this wise: I have been in telegraph offices when lightning struck at some place nearby, and have been near a telephone when lightning also was nearby, and I found that the relays went click, click, click. They acted as if they had received a direct current—no high frequency, pure and simple, would have induced such an effect in the relays; it would instead have jumped the relay and sparked across the terminals.

So, also, everybody knows that during a thunderstorm a telephone bell is frequently rung—which means that a current went through the numerous turns of the electromagnet. That could not be induced by high frequency, it was induced by a steep wave front and not obliterated by the reversal of the phase of the wave, as would be the case with high-frequency effect.

I quite agree with Mr. Creighton in the assumption that there may be in the length of a long discharge to earth some parts where there is oscillation, but if I were to picture the effect, as it occurs to me, it would be about as follows:

I will first make the statement that I do not think it is quite the thing to consider a cloud as a charged conductor. That statement I have made many times. It is not a conductor. It is a very poor conductor—it is a mass of fog. You cannot locate charges on it as you can on a tinfoil condenser. The cloud has plus or minus charges all through. They tend, naturally, to approach the earth, which has the opposite charge.

Somewhere in this system, perhaps where the cloud dips down a little, over an object on the earth's surface a little higher than the rest, there is a beginning of the breakdown. No doubt it begins as accumulation of a free charge and rapidly develops into a discharge. It discharges the lower part of the cloud, and as that begins to discharge the rest of the cloud starts to feed into it, the cloud path ramifying like tree branches in all directions.

Many photographs, even the photographs shown on the screen a short time ago, show two other discharges in the same field, fine discharges, leading down this way and that; what are they? They are the perspective projection of the more or less horizontal discharges miles away in the cloud and feeding the main discharge.

I have one particular picture, which I wish I had brought along with me, which shows a tremendous discharge in the middle distance, and then down to the far horizon of the picture, from this main discharge point, there are branching discharges which apparently lead away in all directions. It is like a great tree the branches feeding into one massive spark. Now, if that feeding distance is five or even ten miles, as it may easily be, then, the limit of rate of breakdown being the velocity of light, high frequency is forbidden. I mean by this that if the energy is to oscillate through the whole length of such a long path of discharge it cannot do so at a high frequency, for during a quarter wave it will need to travel say five miles. The highest possible speed is light velocity, and even at that speed the period is not above 9000 per second.

On one occasion I heard a thunder clap which had a true musical sound, like the sound of a bell. I was convinced in that case that it must have been a discharge of relatively low frequency, I should say not more than three hundred or four hundred vibrations per second.

I have been asked to state why it is that barns are struck by lightning so often, especially when they have moist hay, etc., in them. They are struck pretty often when they have no hay in them, and I do not know that the moist hay has much to do with it. If they are struck by lightning while the hay is in them, they may be burned; if they are struck by lightning when there is no hay in them, they may not be burned. Of course, the combustible material takes fire very readily. That may be the difference. But let us ask—why is the barn struck primarily? Because it has one of the best grounds that can exist. The ammonia salts, the drainage from the cows and horses, soaks into the earth, and that forms a direct connection to the earth. That is why the barn is struck. Why is a barn equipped with lightning rods, which take the charge directly to the ground, struck by lightning and destroyed? Because no conducting ground outside the barn can be compared to the splendid ground which exists inside the barn. We would naturally expect the lightning to go to the best conductor, the best ground on the premises. Let me emphasize this. It will take the best ground on the premises, and that is within the barn. The moral of it is that lightning rods should be anchored where the *best ground is obtainable, in all cases*—something which is quite generally forgotten in providing lightning protection.

I have very little confidence in investigations in lightning phenomena made with small apparatus like the ordinary static machine. In the first place, you cannot imitate a cloud, no mat-

ter how you try, you cannot get any representation of it, by any machine. Among others, Sir Oliver Lodge made some investigations in that way. He used a copper sheet to represent a cloud—mounted below it little rods of copper, iron, and different substances, and then concluded, because he got the snappiest spark with the copper, that copper was the worst material of which to make a lightning rod, and that iron was a very much better material. When we go back to the figures I gave before, and the photographs of lightning discharge I have considered which show a tremendous stroke of lightning falling on a house—the house is about 20 feet high—the spark runs up to the clouds, and ramifies in it miles away, we ask—What influence can a rod of copper or iron have on the character of that discharge; a few feet of rod on a few miles of spark? What is his conclusion worth, where the spark is miles long, and the lightning conductor is an almost infinitesimal part of the path?

In regard to the residual discharge of the Leyden jar, we have taken that to mean that a part of the charge soaked into the glass, and that when we discharged the jar there was need of time for the glass to deliver the soaked charge to the coat of tinfoil. This leaves a slight charge which can give a residual discharge. It depends on a known property of glass, called soakage. We have nothing of that kind in the case of lightning, necessarily.

It is very easy to understand, it seems to me, why with lightning we should observe repeated discharges down the same path. The first discharge establishes a fairly good conductor to ground and some other charged portion of the cloud, more distant, now finds it easy, as it were, to take up that path and discharge; but this will not be instantaneous. It takes some time, according to the velocity of light, for stresses to arrange themselves for the second discharge. Thus there is a slight interval before the charge reaches its full amount and takes the path opened by the first discharge.

W. J. Humphreys: There is one point I want to call attention to. I will not go into a discussion of the entire paper, though it is very interesting to me. This subject has interested me very much in the last three months. The point I have in mind covers one thing which has not been mentioned, as a possible evidence against the oscillating nature of the discharge. We will often find in a discharge of some kind or other, going down, where there are short breaks, secondary discharges going off from it in branches, just as we have in the case of the ordinary discharge between the terminals of an ordinary alternating-current machine. But when we examine these with a rotating camera we never find that they come back in that way, they are always going off in the same direction, whatever direction it may happen to be. You do not find succeeding discharges going in the opposite direction, which we might possibly expect—that we would have a discharge going first in one direction and then in the opposite

direction. In the case of the succeeding discharges, we will find in some few cases—in exceedingly few cases, but in some cases—that there will be a feeble discharge passing off in the same direction. Sometimes it may be that there go out directly a dozen branches in all. This shows, since the branching may occur a second and third time, that if you had them oscillating you could probably get them going that way, as well as this way, but you do not find that.

In the case of the lantern slides shown a short while ago, there is one particular point in regard to them that Dr. Olshausen understands possibly better than I do, but I have had occasion to study exactly the same phenomena. I feel convinced, with these two discharges that come down, one apparently being instantaneous and done with, and the other one that repeats itself, that the two start out in identically the same manner, and in the subsequent case the main branches break off and divide.

George R. Olshausen: I would like to say that these two discharges are entirely separate and the time between is 0.129 of a second. They have been calculated. They are not connected, they do not run down the same path. The time is calculated by taking a photograph with the stationary camera, and at the same time with the moving camera, and it is easy enough to calculate the time between the two flashes.

Professor Walter, of Hamburg, has photographed sparks having a frequency of 300,000 per second. The trouble with our lightning photography is that we have a flash which has a duration of a very short period of time, combined with high frequency, and in trying to photograph that we must be sure that the first registration is not wiped out by the successive flashes which may take place. We therefore must make our registration on a spiral, or something of that kind, so that when we think we have any evidence of oscillations they may not be wiped out by the succeeding flashes.

Trygve D. Yensen: A few years ago I became interested in an investigation conducted by Professor E. J. Berg of the University of Illinois to determine the character of lightning discharges. During this investigation a few preliminary experiments were conducted in the laboratory by discharging sparks from a static machine and Leyden jars through a circuit containing a resistance, an inductance and a condenser in series, each one being shunted by a spark gap. The spark gaps were adjusted, until the distances were found that corresponded to the voltages across the resistance, inductance and condenser respectively. The experiments showed that the voltage across the inductance was practically zero, while that across the condenser was beyond the limit of the apparatus. This result, after making numerical calculations, pointed towards a unidirectional discharge. Although these experiments were not conducted with refined apparatus, they confirm the results obtained by Mr. DeBlois.

The main part of the investigation was carried out with apparatus similar to the ones described above, but placed upon six separate poles, 40 ft. high, distributed 100 ft. apart in an open field. The recording apparatus were connected in series with lightning rods, thoroughly grounded and extending above the tops of the poles. This outfit has now been in the field for four years, and although lightning storms have been quite frequent, the only record obtained has been of minute discharges across the condensers. Not a single direct discharge to the rods has taken place. At one time a barn 2000 ft. away was struck by lightning and burned down, but even then the record obtained was only a small discharge across the condenser. Similar results were obtained from an outfit erected near my residence. Here the lightning rod was placed in a tall tree, extending 80 ft. above ground.

Although our experiences have been mostly negative, they may be of some value when considered in connection with the important results obtained by Mr. DeBlois.

L. A. De Blois (by letter): In preparing this paper the writer made no assertion that the current in all lightning discharges was unidirectional, but pointed merely to the fact that the comparatively few records obtained on the oscillograph seem to indicate that the currents in the particular discharges that occurred at that time were in the main unidirectional.

Mr. Creighton casts some doubt on the action of the oscillograph under high frequencies. It so happens that some special investigations were made by myself along these particular lines. I found that the oscillograph would respond ballistically to a Leyden jar discharge estimated at 3,000,000 cycles when passed across a spark gap into the instrument. On further investigation, however, it was perceived that the estimate of the frequency was entirely wrong on account of failure to take into consideration the resistance of the spark gap itself. When the length of this was reduced so that its resistance became inconsiderable and the discharge current actually approached the estimated frequency of 3,000,000, the oscillograph ceased to respond, except by having its elements burned out without deflection. When tested at somewhat lower frequencies its working limit, so far as response to the oscillations was concerned, lay somewhere above 80,000, at which point it became impossible to obtain a record on the photographic film—the limit being fixed by the sensitiveness of the latter to a rapidly moving spot of light of the intensity available. Since the summation of a high-frequency oscillating wave should be nearly zero, I cannot see why we should expect the oscillograph to act otherwise.

Professor Thomson has cited a number of very interesting points that have led him towards the unidirectional theory of discharge, and to these I can add one which seems to somewhat oppose Mr. Creighton's suggestion that oscillations could occur

more readily in the part of the discharge from clouds to earth, than in the ramified discharges among the clouds. If a high-resistance telephone receiver is connected directly between a wireless aerial and the earth, without other inductance or capacity, it will be found that discharges between the clouds produce a rough crackling sound, while a discharge from clouds to earth produces a sharp clicking or series of clicks at intervals suggestive of the " related" discharges of Professor B. Walter, and which correspond, so far as can be distinguished by eye, to the pulsations in the discharge itself. Actually all these latter discharges, that is, the sharp clicks, are preceded by more or less prolonged noises of the former variety, which, I imagine, indicate the breaking down of the air in the body of clouds—in fact, the "progressive breakdown" described by Dr. Steinmetz. For the same reason I ascribe the sharp clicks to the disruption of the atmosphere between earth and clouds, the sounds of which certainly do not suggest the existence of high or even moderate frequencies.

I think almost all of us have become so attached to the high-frequency theory of lightning discharges that it is very difficult to conceive of anything else occurring. Perhaps, also, some of the discharges in the laboratory which we have heretofore considered high frequency are after all only unidirectional discharges of exceedingly steep wave-front. After all, there is very little difference between the two, since the rapid rise of current from zero to maximum in the latter type of discharge is practically equivalent to the first quarter period of an oscillation, if its frequency is sufficiently high. Over and beyond this, the effects produced by the two will be practically identical except where resonance conditions are involved.

DISCUSSION ON "SOME SIMPLE EXAMPLES OF TRANSMISSION LINE SURGES" (FRANKLIN), WASHINGTON, D. C., APRIL 24, 1914. (SEE PROCEEDINGS FOR APRIL, 1914.)

(Subject to final revision for the Transactions.)

J. Murray Weed: The steepest wave fronts which are produced in the practical operation of electrical systems are those caused by the sudden making or breaking of a circuit. A discharge to ground would come under this classification, although this may not constitute the making of a circuit which it is desired to make. It does not seem likely, however, that the making of a circuit, which takes place by the rupturing of air, oil, or some other dielectric, would result in the rectangular waves which are presented in Dr. Franklin's paper. When we consider the velocity of 186,000 miles a second, it becomes obvious that a phenomenon which is instantaneous, so far as our ability to measure time is concerned, may distribute its effects over a very considerable length of a transmission line. Furthermore, it is my belief that if, by any means, a perfectly abrupt or sheer wave front were produced in a transmission line, it would be very rapidly decomposed, and that at a considerable distance from the point of its formation it would have become considerably tapered.

We do have good evidence, however, that wave fronts may be produced which are so steep as to be dangerous to the turn-to-turn insulation of inductive apparatus; sometimes so steep in fact, as to rupture insulation which has been specifically designed to withstand this sort of disturbance. Moreover, there is no doubt that most of the voltage disturbances in transmission lines originate as traveling waves, or impulses. The method of treatment used by Dr. Franklin is very useful in investigating the behavior of such disturbances and also in investigating various methods of protecting from these disturbances. They have been used already to good advantage by several German writers, notably K. W. Wagner. I myself have been making a study of this nature, some of the more important results of which I hope to publish in the near future.

The written discussion which I have submitted gives a treatment somewhat parallel to Dr. Franklin's, in which I have undertaken to make the subject of how and why waves travel, clear to one who has not given the subject any study, but who has, to begin with, merely a fundamental knowledge of inductance, capacity and resistance. It may be, also, that a concise statement of this matter will be of interest to those who are more familiar with the subject.

J. Murray Weed (by letter): If we consider a generator, of zero impedance and of voltage E, connected instantaneously to a pure inductance, the result is a gradual growth of current, such that

$$L\frac{di}{dt} = E \tag{1}$$

The current which enters the inductance at one end is leaving it at the other end at the same instant, since there is no capacity within the inductance for storing up current. The value of L involved in equation (**1**), therefore, is the total inductance, and since there is no resistance, the growth of current is uniform and continuous.

If the same generator be suddenly connected to the end of one wire of an indefinitely long transmission line of zero losses by closing the switch, our conception of the method in which the line would be charged is as follows:

The capacity of the first element of the line is instantly charged. But current must flow through the inductance of this element to charge the second element, and this requires an instant of time. After the second element is charged there is no further growth of current in the first element, since there is no difference of potential applied to this element. The current set up at the first instant merely continues to flow, supplying the necessary charging current for successive elements of the line, and current grows in but one element at a time this growth being by an instantaneous change from $i = 0$ to $i = I$. The current I and the electrostatic charging of the line to voltage E advance together with a sheer wave front, so that the total voltage of the circuit appears at the front of the wave. We find the relation between this action and the growth of current in the pure inductance of the first case, as follows:

Equation (**1**) may be written in the form

$$d\frac{(Li)}{dt} = E \tag{2}$$

and for the transmission line, since we assume an instantaneous growth of current from zero to a constant maximum value in successive elements of inductance, we may say that we have constant current, with gradual increase of inductance, so that equation (**2**) becomes

$$I\frac{d\,L}{dt} = E \tag{3}$$

If L_0 = the inductance per unit length of the line, this becomes

$$I\,L_0\frac{dy}{dt} = E$$

or (**4**)

$$I\,L_0\,dy = E\,dt$$

where y = distance along the line.

If Y = the total length of the line, and T = the time required for the charging wave to traverse the line, the integration of equation (**4**) gives

$$I\,Y\,L_0 = E\,T \tag{5}$$

Considering now the relation between current, voltage, and the capacity of the line, we find similarly the equation

$$E\, C_0\, dy = I\, dt \tag{6}$$

where C_0 is the capacity per unit length of the line. The integration of this equation gives

$$E\, Y\, C_0 = I\, T \tag{7}$$

From equations (**5**) and (**7**) we obtain directly the time required for the charging wave to traverse the line,

$$T = Y\, \sqrt{L_0\, C_0} \tag{8}$$

and since the velocity equals the length of the line divided by the time, we have

$$v = \frac{1}{\sqrt{L_0\, C_0}} \tag{9}$$

From (**5**) and (**7**) we also obtain

$$\frac{L_0\, I^2}{2} = \frac{C_0\, E^2}{2} \tag{10}$$

Since the first member of this equation represents the electromagnetic energy per unit length, and the second member the electrostatic energy per unit length, equation (**11**) shows the equality between the electrostatic energy and the electromagnetic energy of the advancing wave, which is a characteristic of all pure traveling waves. The total energy per unit length of the charging wave thus is

$$W = \frac{L_0\, I^2}{2} + \frac{C_0 E^2}{2} = L_0\, I^2 = C_0\, E^2 \tag{11}$$

This energy per unit length multiplied by the velocity of the wave gives the power absorbed from the generator. Thus, from equations (**9**) and (**11**),

$$P = L_0\, I^2 \frac{1}{\sqrt{L_0\, C_0}} = I^2 \sqrt{\frac{L_0}{C_0}} \tag{12}$$

and

$$P = C_0\, E^2 \frac{1}{\sqrt{L_0\, C_0}} = \frac{E^2}{\sqrt{\frac{L_0}{C_0}}} \tag{13}$$

So far as the generator is concerned, with an indefinitely long transmission line, this power is lost, just as much as though it had been consumed by the resistance

$$R_0 = \sqrt{\frac{L_0}{C_0}} \qquad (14)$$

The quantity $\sqrt{\frac{L_0}{C_0}}$ is, in fact, measured in ohms, and may be called the wave resistance of the line.

From the equation (**11**) or directly from equations (**5**) and (**7**), we have also

$$I = \frac{E}{\sqrt{\frac{L_0}{C_0}}} = \frac{E}{R_0} \qquad (15)$$

Thus Ohm's law may be applied to a transmission line with respect to traveling waves, and shows how much current will flow into the line with a given voltage applied. This must be restricted, of course, to the initial period of charging the line.

If we examine a point in the line after the wave front has passed we find the constant current I flowing at the constant voltage E, which is the generator voltage, supplying the power

$$P = E\,I = I^2 R_0 = \frac{E^2}{R_0} \qquad (16)$$

These values of P are the same as that given by equation (**13**)

Now, if the generator voltage is suddenly reduced to zero, current ceases to enter the line from the generator. One might, at first thought, expect the current to begin to flow back from the line into the generator. This, however, is not the case. The wave of current and voltage continues to progress in the line. The rear end of the wave is similar to the front end, except that the voltage E existing in the line, here acts in a direction toward the generator, instead of away from the generator, and we have here a counter e. m. f. which is away from the generator, due to the cessation of current in that inductance from which the rear end of the wave is passing, whereas the counter e. m. f. at the front of the wave is toward the generator, due to the current entering the inductance which is in advance of the wave. Kirchoff's law for voltage is satisfied at both ends of the wave, as expressed for the front end by equation (**4**). The same equation may be used for the rear end, but the opposing e. m. f.'s are reversed with respect to the positive direction in the circuit. If we change signs on both sides of the equation to account for this, we have

$$-I\,L_0\,dy = -E\,dt \qquad (17)$$

This equation for the rear end of the wave may be looked upon as belonging to a wave front of opposite polarity, the front of a wave of negative current and negative voltage, superposed upon the former wave of positive current and positive voltage, and thus reducing both current and voltage to zero.

The above deductions were made with respect to an abrupt or sheer wave front. If a practical generator, or generator and step-up transformer, of large inductance, be suddenly connected to the end of a line, the charging wave will not be abrupt, since the current I must grow in the inductance of the generator. The growth of current and voltage at the entrance of the transmission line are logarithmic, as expressed by the equations

$$i = \frac{E}{R_0}\left(1 - e^{-\frac{R_0}{L}t}\right) \tag{18}$$

and

$$e = E\left(1 - e^{-\frac{R_0}{L}t}\right) \tag{19}$$

where $R_0 = \sqrt{\frac{L_0}{C_0}}$ is the wave resistance of the line, as found above for the abrupt wave, L is the inductance of the generator and t is the time measured from the instant of closing the switch. Substituting the value

$$t = y\sqrt{L_0 C_0} \tag{20}$$

these equations become

$$i = \frac{E}{R_0}\left(1 - e^{-\frac{L_0}{L}y}\right) \tag{21}$$

and

$$e = E\left(1 - e^{-\frac{L_0}{L}y}\right) \tag{22}$$

which give the current and voltage at a point in the wave distant y from the tip of the wave, which entered the line at the first instant.

That such a tapered wave, or in fact a wave of any shape, will follow the same laws as the wave with abrupt front and rear, is easily inferred by thinking of the tapered wave as made up of infinitesimal abrupt waves, distributed in time, or in space. Equations (4) and (6) can be applied to each of these differential waves and integrated with respect to distance and time, giving in lieu of equations (5) and (7),

$$di\, Y L_0 = de\, T \tag{23}$$

and

$$de\, Y C_0 = di\, T \tag{24}$$

All of these differential waves, therefore, follow the same laws of propagation, reflection and refraction as a finite abrupt wave.

Thus, the velocity of each element of the wave will be the same, and the same proportions are reflected, and refracted. The wave shape of the tapered or irregular wave, obtained by the superposition of all of the differential elements, is therefore preserved, and the same proportionality will exist between the original wave and its reflections and refractions as with the abrupt wave; although this statement would have to be modified where the reflecting agent is reactive.

Some consideration of the nature of so-called reflections of the traveling wave will make this subject clearer to those who are not already familiar with it. Thus, for instance, at the instant when the abrupt wave reaches the end of the line, we find the entire line charged to voltage E, and the current I flowing throughout its length. The condition at this instant is the same, whether the line be open or closed. If the line is open, since the current can not flow out at the end of the line, it supplies additional charge to the end of the line, and so builds up the voltage to a higher value than E. The question as to how high this voltage will build has been answered by saying that the wave is completely reflected, with negative current and positive voltage, this reflected wave superposed upon the oncoming wave giving zero current and double voltage.

This statement, however, does not give the true fact, but a fictitious condition which is equivalent to the fact. The fact is that the line retains its charge corresponding to the voltage E, while the current I acts in the same manner as it would if it had been flowing through the line, with no voltage at all present, and were suddenly interrupted at the end of the line. With the building up of a certain voltage E' in the last element of the line, current must cease in the next to the last element. Otherwise the voltage would continue to build up indefinitely. Voltage will then build up in the next to the last element, with cessation of current in the preceding element, etc. The voltage E^1 is acting in a direction against the current or the negative direction, while an equal counter e. m. f. in the positive direction is produced by the reduction in the amount of inductance occupied by the current I. This balance of e. m. f's is expressed by equation (**4**) with the appropriate changes in signs. Thus

$$I L_0 (- dy) = -E'dt \qquad \textbf{(25)}$$

This equation may be looked upon as applying to a wave of negative voltage and positive current, traveling in the negative direction, and leaving the line charged to the voltage E'. In the case which we are considering, the line was already charged to voltage E, so that the resultant voltage is now $E + E'$.

If we change signs on both sides of equation (**25**), thus transferring it to the other side of the wave front, we have

$$- I' L_0 (- dy) = E' dt \qquad \textbf{(26)}$$

This equation applies to the front of the fictitious reflected wave of positive voltage and negative current, which is supposed to be superposed upon the original wave.

The same considerations which gave us the current which will enter a line with voltage E applied (**15**), will now give us the voltage which will be built up in the line by the current I, namely,

$$E' = I\, R_0 \tag{27}$$

If reference is made to the fictitious reflected current, which is no doubt the more convenient, we must take account of the negative sign, and (**27**) becomes

$$E' = -I'\, R_0 \tag{28}$$

where I' is negative.

In the case of the closed-ended line, instead of the line retaining its charge corresponding to voltage E, and the current I building up an additional voltage, E', which is equal to E, we find that the current I is uninterrupted, while the voltage E is permitted to set up an additional current I', which is equal to I. Equation (**28**) applies here also, but in this case I' is positive and E' negative.

Professor Franklin has spoken of the effects of line losses as usually small. It can be shown that as ordinarily considered, they have no effect in destroying the abruptness of the wave, but that they reduce the height of the wave front in accordance with the equation

$$E_y = E_1\, e^{-\left(\frac{g}{2\, G_0} + \frac{r}{2\, R_0}\right) y} \tag{29}$$

where E_y is the voltage at the wave front, E_1 is the voltage with which the wave enters the line, y is the distance that the wave has traveled, g and r are the insulation conductance and the resistance per unit length of line, and G_0 is the reciprocal of R_0, and may be called the wave conductance of the line.

There is, however, another element of loss, and of energy absorption, which exists only in the wave front, and which does destroy its abruptness. The rapidity of this action I have not yet determined. The action referred to is that of skin effect, the current at the extreme front of an abrupt wave being all at the surface, and becoming gradually diffused after the wave front has passed. I have found that the energy subtracted from the wave within the region wherein this diffusion takes place, corresponds to a resistance of 30 ohms.

With a perfectly abrupt wave front this resistance will be effective with respect to the total current at once, and so will decompose the wave front rapidly. As soon as the wave front becomes tapered, the extra wave front resistance will be effective with respect to only a part of the current at a time, and the energy absorbed is thus reduced, as well as distributed over a greater distance, or longer portion of the wave. This process

of reducing the energy absorbed, and distributing it over greater distance, goes on progressively.

A. G. Webster: To allay the doubts of the last speaker, Mr. Weed, who said that it was impossible for the corners to persist, I will say that that is absolutely true in real lines, but Dr. Franklin has the gift of making things very simple by making certain assumptions.

Some of us are familiar with sound. It happens that sound waves are easier to experiment on than electric waves. The theory given by Dr. Franklin, and the theories advanced in the papers by Mr. K. W. Wagner, in which you will find a number of oscillograms, show these things, how you may have corners in a real circuit, though the corners round off, and the theory is exactly the same as the transmission of plain sound waves. You know that organ pipes correspond exactly to the circuit with a certain amount of inductance, and with a certain amount of capacity, which is elasticity of air. Any wave that enters at one end proceeds to the other end, and is reflected back if the end is open. If the pressure is that of the open air there cannot be any difference, and the pressure wave is reflected back. So, if the end is open there can be no current, and the current is reflected back. On the other hand, if the end is closed, there can be no displacement, because air cannot move against a wall, it being a longitudinal wave. If the electrical wave has an open end where there is no current the potential is doubled. Say that a wave runs back and forth in this tube, it is different at the two ends and has to go back and forth four times before it gets to its former condition, and, therefore the wave length will be four times the length of the tube.

Twenty-one years ago I made some experiments on these surges, not on a cable, for I had none, but on a wire some five or six hundred feet long. On the basis of my experiments I announced that I would present a paper at the International Electrical Congress in Chicago, in 1893, spoken of by President Mailloux earlier this evening. I made a few experiments, enough to justify me in sending in the title of the paper, but as it developed, they were not enough to justify the preparation and reading of a paper, so I withdrew it. The apparatus with which to conduct the experiments was made, but on account of mechanical difficulties it was put aside. Since Dr. Whitehead asked me last week if I would speak on this paper, I have put up a wire again, and made further experiments.* I may say that all of Mr. Wagner's experiments were made on an artificial line, a very remarkable line made of coils and condensers and representing all sorts of cables and all sorts of lengths, and his conditions, though simpler, are more like reality than Dr. Franklin's, for he allows you to put in a damping term. My own experiments have borne out the same idea. Such a wave, instead of being a ribbon wave, falls off, as was stated by the last speaker. There is a corner on it, but

this corner goes along with the velocity of light, and when it has reached a given point, it has fallen off by a definite fraction. I showed the proof of that in my book some seventeen years ago. The theory was given some twenty-five to thirty years ago by Oliver Heaviside.

This line that I speak of was merely a copper wire strung up, and a charge is put on. The other end of the wire, which has been brought back by a sufficiently remote route, is connected with an electrometer, and about two-millionths of a second after this discharge has been put on the electrometer is disconnected. The thing is done again, moving the micrometer up so as to make it, say, a millionth of a second, but as this line was only three hundred meters long, it took a millionth of a second to traverse it, and you see the instrument is put under very serious demands, and I am free to say it is not sensitive enough to give satisfactory performance on a very short line. I would like to have a line two or three miles long. A battery is put on here—we will say it is positive. You can easily see that the electrometer can give absolutely no negative readings unless there are surges. As a matter of fact we get a certain number of positive readings scattered around, but we get some negative readings, at least half as big as the positive readings. My instrument is not perfect, but it is sensitive, it will measure to one two-millionth of a second, but it will not do the same thing for one ten-millionth of a second. If I had a longer line I could show these things in a better experiment. That is the experiment I tried to do twenty-one years ago—I did not forget it, but put it aside, and last week I got what I may call positive results.

As has been said, in a real line the wave goes to 186,000 miles per second, but few lines are as long as that. These things happen quickly; that they are real no one doubts; that the potential may be doubled and climb up by steps, etc., all those things are a consequence of theory.

In these papers of Dr. Wagner's you will see real oscillograms; the whole thing is very clear. There is a charge put on a resistance, the potential rises immediately, falls a little, goes up again, and comes back, and so on, and this approaches an asymptote, and then the potential goes down, by successive steps. This was not on a real line, it was on an imitation line, but I presume everybody here believes a statement of Prof. Pupin, which he has evolved from his experiments, that such lines do imitate the real lines to great perfection, provided the coils are subdivided finely enough.

A. Hamilton-Ellis (by letter): I do not agree with the author that very little need be said in connection with the opening of switches on short lines.

In a case which occurred some time ago, at the station where the writer is, the switching-off of a bank of three single-phase transformers, connected in delta on the primary, for supply-

ing a 750-kw. synchronous converter, resulted in wrecking the switch and almost wrecking the cell structure. The transformers were only energized at the time, the converter being shut down.

The supply was at 6600 volts, 25 periods, with one phase earthed, the neutral of the generator being insulated. Between the switch and transformers were approximately 90 ft. of three-core, paper-insulated, lead-covered cable of 0.075 sq. in. section. An examination of the switch, or what was left of it, showed the appearance of an arc having been broken, but it was extremely doubtful.

However, doubts were soon put at rest, for, shortly afterwards, one of the transformers, which had the appearance of an arc having taken place inside it, was disconnected and a generator was run directly upon it. The connection between the generator switch and the transformer was made with 7/16 stranded cable, one pole being grounded. On reaching 6600 volts, the generator switch was accidently opened, with the result that the switch was wrecked, this wrecking taking place across the terminals outside the switch. An examination of the switch contacts failed to show any sign of an arc having taken place, and the transformer was later found to be all right.

Further tests were carried out with an oscillograph, when it was found that the voltage rise was approximately 5½ times normal, when the switch was opened with these transformers on magnetizing current alone.

Perhaps the author will be able to give a reason for the occurrence. Allowing that in the first instance an arc was drawn out and that the condenser effect of the cable was sufficient to quench it suddenly, the cause is not so self-evident in the second case.

However, the point I wish to bring forward is, that even in the case of the shortest of connecting lines between the generator busbars and the apparatus that is connected thereto, there is every possibility of these surges taking place.

DISCUSSION ON "THEORY OF THE CORONA" (DAVIS), WASHINGTON, D. C., APRIL 25, 1914. (SEE PROCEEDINGS FOR APRIL, 1914.)

(Subject to final revision for the Transactions.)

J. B. Whitehead (by letter): Professor Davis's paper is noteworthy as being the first thorough-going attempt to explain the phenomena of corona formation in terms of the theory of ionization. In each of the papers of my series on *The Electric Strength of Air*, I have stated my opinion that the phenomena in question would ultimately be explained in terms of that theory. Professor Davis is the first, however, to offer to the Institute a theory which begins from the fundamental relations given by Professor J. S. Townsend, the originator of the theory of ionization by collision, as the explanation of all electric discharges in gases. Professor Davis makes a number of assumptions which will require careful investigation before acceptance. Among these is that which states as the critical condition for corona formation that the density of ionization at the surface of the wire should reach a constant value. In the process leading up to the arrival at this value he assumes a continuous generation of new ions by collision beginning a certain distance from the wire and accumulating in time through successive cycles of the alternating electric intensity. If this is true, should there not be evidence of ionization for values of voltage just short of the corona-forming value? Our experiments have indicated no such preliminary ionization.

I should like to ask the origin of Professor Davis's figure of 26,000 volts per cm. as the value of X_0.

The correctness of the development of Professor Davis's theory depends largely on the value of α as given in formula (7). It would be interesting to know what other evidence there is in support of this value.

Professor Davis has evidently given careful thought and study to the relation of his theory to the results which have been presented in papers to the Institute. Indeed, the agreement between the theory and observations is so remarkable that it is to be hoped that Professor Davis will in a further paper discuss the possible errors introduced by several assumptions which he has made in the reasoning. I have not found it possible to check them all.

It may be well to call attention that Professor Townsend has himself offered an explanation of the relation obtaining between the critical corona intensity, the diameter of the wire and the density of the gas, in an article in the London *Electrician* for June 6, 1913.

Harris J. Ryan (by letter): The Davis theory of corona presents for the first time a definite and satisfactory correlation of the essential factors that cause corona formation on high-voltage transmission lines. The theory has not been extended, as yet, so as to account fully for *local corona* that generally precedes full corona formation, and for the strength of the corona-formed

ionic (in phase) current in relation to frequency and voltage. This does not lessen its integrity nor its value. Merely its opportunity for growth is thus emphasized and such growth will be sturdy. In due course of time it will be extended so as to account for most if not all of the corona phenomena.

The author's fundamental assumptions in regard to the dual origin of the n_0 ions and the corona-culminating role of the n ions are made upon firm ground. Assumptions employed in the construction of a satisfactory theory must be nominated by corresponding facts. The Columbia University experiment which demonstrated the time lag of the arrival of the initial corona has contributed an important nominating fact in regard to the n_0 ions. We have found in our own work that the normal critical visual corona-forming voltage applied to parallel wires may be lowered greatly, as much as fifty per cent, by liberating near such wires an independent supply of ions. This was done by mounting a fine wire between the high-voltage wires and charging it from a static machine. Objection to this experiment was made on the ground that the electric field about the high-voltage wires is increased by the presence of the charged fine wire. So it is, but the increase is far too little to account for the results. This has been demonstrated by computation and experiment. The results of the experiment fortify the author's assumptions that corona formation is dependent upon the initial supply of free ions, N_0 and " that the discharge will appear when the ionization per unit area at the surface reaches a certain constant value, n." Also that " the density of ionization at the surface of the conductor will increase somewhat without ionization by impact as the N_0 ions move inward."

We have been working during the past two years with a steady, undamped, high-frequency, high-voltage source and have observed that coronas formed at 60,000 cycles per second consume large amounts of power and develop correspondingly high temperatures. These corona temperature effects continue to increase with frequency increase. The highest frequency used has been 600,000 cycles. The values of such steady high-frequency high voltages required to discharge across sphere gaps are much the same as the corresponding values at low frequencies. The corresponding voltages required to discharge through corona-forming blunt-pointed gaps are generally about one-half those required at low frequencies. Large, vigorous, local high-frequency corona brushes are formed on slight provocation at abnormally low voltages. A brush of this character may be blown by lung power from the point of the circuit where it originated to another point whereat it could not be started by the unaided action of the circuit supplied by a given voltage. These corona brushes may also be started at sub-critical voltages by touching the circuit momentarily with a stick of wood. The corona brush will start at the spot on the conductor touched by the wood. In these high-frequency phenomena we have much evidence of

the correctness of the author's implied assumption that the number of ions maintained in action, producing in-phase current, depends upon the shortness of their amplitudes of actual travel and of intervals of replenishment, *i.e.*, upon the frequency of the source.

Edward Bennett (by letter): The paper on the *Theory of Corona* contains a derivation from rational considerations of an equation which fits certain curves experimentally determined by Peek, Whitehead and others. These curves show the relation between the radius of wires of different diameters and the hypothetical gradients at the surface of the wires which cause ionization of the surrounding air to become evident.

The justification for some of the rational notions made use of by the author is not at all clear to me, while other assumptions do not seem to be in accord with the interpretation to be placed upon the experimental data. For example, it seems to be assumed that ionization will first be evident during that half-cycle of the alternating wave in which the electrons are moving inward across the surface Q of Fig. 1 toward the surface of the wire. Now, oscillograms taken at air pressures in the neighborhood of one cm. of mercury show that as one gradually raises the voltage between wire and surrounding cylinder, there is quite a range in voltage during which copious ionization occurs only during the half-cycle in which the wire is cathode, or the electrons move outward. At atmospheric pressure it is impossible to tell from the oscillograms the polarities under which copious ionization sets in. That is, as one slowly raises the voltage between the wire and surrounding cylinder the oscillograph gives evidence of ionization at substantially the same impressed voltage at which the eye sees the bluish haze around the wire. In addition the oscillograph also shows that ionization is occurring not only during the half-cycle in which the wire is positive but also during the half-cycle in which the wire is negative to the cylinder. This would seem to indicate that ionization resulting from both positive and negative ions should receive consideration in any derivation of the relation between the critical gradient and the radius of the conductor.

Referring to equations (5) and (6) the author makes the statement: "An inspection of Fig. 1 will show that the number of n_0 ions, crossing the surface Q per unit area, varies inversely as b; consequently, we may approximately assume that the whole term on the left is a constant for first appearance of discharge." It is not clear to me either why n_0 varies inversely as b, or why the left member of equation (6) may be regarded as approximately constant, and it would be gratifying if the author would elaborate on these two assumptions.

Alex. Chernyshoff (by letter): Mr. Davis and Prof. Townsend in their work have taken into account only the kinetic energy of the electrons and positive ions, leaving entirely out of consideration the possibility of the influence of the electric field on the

molecules themselves. Under action of the electric field the inner cohesion between the electrons and positive ions may be weakened within the neutral molecule. In consequence of this weakening, a smaller amount of kinetic energy will be required for the process of ionization. The inner cohesion between the positive and negative ions varies with the nature of the gas. In some cases the effect of this degree of cohesion may be considerable. The exception presented by helium seems to be especially interesting. The density of helium is double that of hydrogen. The average free path in hydrogen ought, therefore, to be twice as long as in helium. In accordance with Hr. Townsend's theory, it is necessary to assume that the negative ion comes twice as many times in collision (5:2.4) passing through a certain space in hydrogen as it does in helium under the same pressure. Is it not reasonable to conclude that this exception is due to the influence of the field on the neutral molecule itself?

For the further elucidation of my explanation let us consider the following: Let us suppose that we have to do with a gas having no free ions and from which all ionizing influences are removed. When acted upon by a high voltage, theoretically there ought not to be any discharge produced in that gas, no matter how high the tension may be. Of course, it is hardly possible to be certain in concrete cases that all sources of outside ionization are actually absent, in view of the omnipresence of radioactive substances, but if all such substances were removed a certain tension higher than usual would produce a discharge in the gas.

It seems to me that in considering the question of the causes of the appearance of corona, it is necessary to take into account the influence of the field.

In the second statement of the author, when pointing out the interdependence between the diameter of the conductor and the surface gradient necessary for the appearance of corona, it was assumed that the field had a logarithmic distribution, *i. e.*, the absence of free electricity between the conductor and the cylinder or the earth was assumed. In some cases, for instance, when the distance between the cylinder and conductor is small, this assumption, perhaps, does not introduce any significant error. But as soon as the diameter of the cylinder reaches the dimension of 40 cm., the discrepancies in the distribution of the field, as pointed out by Starke, may reach 10 per cent even in the most simple case. When the distance is larger, the effect on the distribution will be still greater. In view of the complexity of the problem in the case of alternating currents, I will point out here the dependence between the gradient of the field and the constant of the ionization and the diameter of the cylinder, for a constant electric field and when the ionization is not caused by collision but is caused by the influence of an outside force. If we indicate the number of ions on each square cm. of the surface of the conductor during one second by N, the density of current by i, the density of free electricity near the surface of the conductor

by ρ, the difference of the potential between the cylinder and the conductor by V, by D and a the diameters of the cylinder and conductor respectively, by e the charge of the ion and by x its mobility, we will get for the density of the current i the following formula:

$$i = \rho\, x \frac{dV}{dz} = N e$$

Applying the equation of Poisson to cylindrical coordinates

$$\frac{\delta^2 V}{\delta z^2} + \frac{1}{z}\frac{\delta V}{\delta z} + \frac{1}{z^2}\frac{\delta^2 V}{\delta \varphi^2} + \frac{\delta^2 V}{\delta z^2} = -4\pi\rho$$

For the given case the equation is

$$\frac{\delta^2 V}{\delta z^2} + \frac{1}{z}\frac{\delta V}{\delta z} = -4\pi\rho$$

or by substituting the value for ρ

$$-\frac{N}{x\dfrac{\delta V}{\delta z}} = \frac{1}{4\pi e}\left(\frac{1}{z}\frac{\delta V}{\delta z} + \frac{\delta^2 V}{\delta z^2}\right)$$

$$-\frac{4N\pi e}{x} = \frac{1}{z}\left(\frac{\delta V}{\delta z}\right)^2 + \frac{\delta^2 V}{\delta z^2}\frac{\delta V}{\delta z} = \frac{1}{z}\left(\frac{\delta V}{\delta z}\right)^2 + \frac{1}{2}\frac{\delta\left(\dfrac{\delta V}{\delta z}\right)^2}{\delta z}$$

The integration of this equation will give

$$\left(\frac{\delta V}{\delta z}\right)^2 = -\frac{8\pi}{3}\frac{e N z}{x} + \frac{C}{z^2}, \text{ or}$$

$$\frac{\delta V}{\delta z} = \sqrt{-A z + \frac{C}{z^2}}$$

where

$$A = \frac{8\pi}{3}\frac{e N}{x} = \text{const.}$$

Neglecting the first member under the radical, we will get the logarithmic distribution of the electric force, for

$$C = \frac{V}{\log\left(\dfrac{D}{a}\right)}$$

The first member will gain more and more in significance as the diameter of the cylinder increases.

When the potential is alternating or variable the phenomena will be very much more complicated and it will not be possible to integrate the differential equation and in this way determine fundamental dependence of the gradient from the diameter of the cylinder and the constant of ionization, but this increased complexity of the phenomena does not change their essential character. I therefore think that when the distance between the earth and the conductor is considerable the variation of the field distribution of potential from the logarithmic curve will be considerable. In the case of ionization through collision there will be an enhanced inequality in the distribution of free electricity due to the difference in mobility of various ions.

In conclusion I want to relate one very interesting experiment demonstrating the action of light on electric discharges. Lebedinsky proved that light can not only facilitate the appearance of an electric discharge in the shape of a spark between electrodes, but that under certain conditions it may check its appearance. The experiment was conducted as follows:

A variable tension was placed near the breakdown. A slight illumination of one of the unsymmetrical electrodes regularly produced the appearance of a spark discharge. When the illumination was strengthened, irregular discharges were produced, and with a stronger illumination the discharges were discontinued entirely, while there was no change in the tension between electrodes. The reason for this phenomenon is the increased number of negative ions changing the distribution of potential in such a way as to prevent a discharge. This phenomenon, viewed from our point, demonstrates the importance of the field distribution and the dependence of the distribution of the free ions in the gas.

F. W. Peek, Jr. (by letter): It may be of interest to state, in a brief way, the manner in which our law of visual corona was derived, and also to call attention to the fact that it is a rational law. In 1910 I conducted an investigation, very carefully determining the visual corona voltages of various sizes of polished parallel wires at various spacings. This was given in my paper before the A.I.E.E. in June, 1911. For any conductor the voltage gradient at rupture, g_v, was found to be constant, independent of the spacing (except at very small spacings), but increased very rapidly as the radius of the conductor was decreased. Thus air *apparently* had a greater strength for small conductors than large ones. This was formerly pointed out by Professor Ryan. The experimental data curve between g_v and radius r was found to be regular and continuous. A number of equations could readily be written which would fit these data. It was desired, however, to establish or build up a rational equation. The old idea of air films at the surface of the conductors was abandoned, after tests with very light (aluminum) and very heavy (tungsten)

metals showed that the density of the metal of the conductor had no influence on g_v, which should be the case if the difference were caused by air films, as the air film should vary with the density of the conductor.

A rational law of visual corona was deduced from the data, reasoning as follows:

Energy of some form—be this the $\sum \frac{m\,v^2}{2}$ of the energy of the moving ions, or whatever form it may—is necessary to rupture insulation. This is borne out by experiment with transients, which show that finite time is necessary to rupture insulation, and that if this time be limited the voltage must be increased to accomplish the same results in the limited time. Heating results at rupture, etc. These facts imply definite finite energy. The gradient or stress to rupture air in bulk in a uniform field, g_0, should be constant for a given air density or molecular spacing. In a non-uniform field, as that around a wire, the breakdown strength of air, g_0, is first reached at the conductor surface; at a small distance from the conductor surface the stress is still below the rupturing gradient. Hence, in order to store the necessary finite rupturing energy the gradient at the conductor surface must be increased to g_v, so that at a finite distance away the gradient is g_0. This means that a finite thickness of the insulation must be under a stress of g_0 or over. The rupturing energy is in the zone between g_v and g_0. The thickness of the zone should be a function of the conductor radius. It was found that at $0.301\ \sqrt{r}$ cm. from the conductor surface the gradient at rupture is always constant and 30 kv./cm. (at standard air density). The relation between g_v and r may now be directly expressed by the simple law

$$g_v = g_0\left(1 + \frac{0.301}{\sqrt{r}}\right) = 30\left(1 + \frac{0.301}{\sqrt{r}}\right)$$

For parallel planes or for air in bulk

$$r = \infty$$
$$g_v = g_0.$$

Thus the strength of air is constant and equal to 30 kv./cm., but in non-uniform fields is apparently stronger, as explained above. If the air is made less dense, that is, if the molecular spacing is changed, the strength of air in a uniform field should decrease directly with the air density.

$$g'_0 = \delta\, g_o$$

However, for non-uniform fields, the energy distance should also change thus

$$0.301\, r\phi\ (\delta)$$

I found this to be borne out by experiment and the complete equation containing air density correction to take the simple rational form

$$g_v = g_0 \delta \left(1 + \frac{0.301}{\sqrt{\delta r}}\right)$$

If the energy distance is limited to less than 0.301 $\sqrt{r}$ the apparent gradient should increase. This also is borne out by experiment, as shown in later papers.* The visual tests on various forms of electrodes—as spheres, wires, planes, etc.—as well as loss measurements, all point to an energy storage distance and a constant strength of air of 30 kv./cm.

At *continuous* high *frequency* where the rate of energy, or the power, is great, frequency *may enter* into the energy distance, thus

$$0.301 \frac{r}{\delta} \phi (f)$$

and spark-over take place at lower voltages. Where the time is limited, as in an impulse of steep wave front, a much higher voltage should be required to start arc-over. This is also borne out by experiment.

Thus far, I have said nothing in regard to the form of this rupturing energy. Such speculation was not necessary in order to develop a rational working equation. After a law is developed it is interesting and instructive to fit speculative theory to that law.

In the discussion of my paper, *The Law of Corona*, 1911, Dr. Steinmetz suggested how the theory of ionization by collision could be made to fit the law of corona which had just been brought out. This suggested application is the same as that followed by Mr. Davis in his mathematical work, and is found on pages 1968, 1969 of the A.I.E.E. TRANSACTIONS for 1911. The theory that initial ionization could not affect the starting voltage is brought out on page 1122 of the A.I.E.E. TRANSACTIONS for 1912. I have also suggested the same application of the electron theory in my papers of 1912 and 1913, and also in discussions. Briefly, the rupturing energy may be the $\sum \frac{m v^2}{2}$ of all the ions necessary to produce ionic saturation, and hence conduction or corona.

When low potential is applied between two conductors any free ions are set in motion. As the potential, and, therefore, the

*See *The Law of Corona and the Dielectric Strength of Air*-II, (Peek), TRANS. A. I. E. E., 1912, XXXI, I, page 1051; and *The Law of Corona*-III, PROCEEDINGS A. I. E. E., June, 1913, page 1335.

field intensity or gradient, is increased the velocity of the ions increases. At a gradient of $g_0 = 30$ kv./cm. ($\delta = 1$) the velocity of the ions becomes sufficiently great over the mean free path to form other ions by collision. This gradient is constant and is called the dielectric strength of air. When ionic saturation is reached at any point the air becomes conducting and glows, or there is corona or spark.

Applying this to parallel wires—when a gradient, g_v, is reached at the wire surface any free ions are accelerated and produce other ions by collision with molecules, which are in turn accelerated. The ionic density is thus increased by successive collision until at $0.301 \sqrt{r}$ cm. from the wire surface, where $g_0 = 30$, ionic saturation is reached, or corona starts. The distance $0.301 \sqrt{r}$ cm. is, of course, many times greater than the mean free path of the ion, and many collisions must take place in this distance. Thus, for the wire, corona cannot form when the gradient of g_0 is reached at the surface, as at any distance from the surface the gradient is less than g_0; a finite thickness of air must be under a stress equal to or greater than g_0. The gradient at the surface must therefore be increased to g_v so that the gradient a finite distance away from the surface ($0.301 \sqrt{r}$ cm.) is g_0. That is to say, energy is necessary to start corona, as outlined above. g_0 the strength of air, should vary with δ; g_v, however, cannot vary directly with δ, because with the greater mean free path of the ion at lower air densities, a greater " accelerating " or energy distance is necessary. In the equation

$a = 0.301\sqrt{\frac{r}{\delta}}$; that is, a increases with decreasing δ.

When the conductors are placed so close together that the free accelerating or energy distance is interferred with, the gradient g_v must be increased in order that ionic saturation may be reached in this limited distance.

Initial ionization of the air cannot affect the starting voltage, since such ionization must necessarily be very small compared to the residual ionization after each cycle. When, however, the initial ionization is very small when voltage is first applied, an appreciable time is necessary before corona starts. The starting voltage, however, is not affected for continuously applied a-c. or d-c. voltage. For transients of short duration, or for single impulse, much higher voltage should be required to produce the same results in limited time—that is, higher impulse voltages should be required to cause corona or spark-over.

Mr. Davis has mathematically connected the theory of ionization by collision with the law of corona already established. His results seem to indicate in a very interesting way that the rupturing energy may be the $\sum \frac{m\,v^2}{2}$ of the energy of the colliding ions. Of course this does not definitely prove this particular applica-

tion of the ionization theory. It shows that by a proper valuation of the constants, his equation will coincide with the established experimental equation. A number of equations might apply in the same way. It is interesting to quote as follows from his paper:

"The fact that equations (**14**) and (**15**) plot into almost identical curves is evidence that the theoretical equations express law of corona as accurately as the empirical equations."

The ionization theory will be more fully established for practical application when we may reverse this statement, or when theory so reaches the stage that we may say, "it is remarkable that the practical results so well check the theoretical ones."

Mr. Davis is to be congratulated upon the important work which he has done in actually applying theory to obtain practical working results. The electron theory has not been so definitely applied before to obtain practical results, but only vaguely and in a speculative way, fitting the theory to suit the particular case. It is such important work that will bring forward and extend this theory.

Bergen Davis (by letter): The discussions of my paper on the "Theory of the Corona" have interested me, and I appreciate the criticisms and suggestions which the various gentlemen have made. It is perhaps not necessary to take time and space for a lengthy reply, but I will consider a few points that seem to need further explanation.

(1) Professor Whitehead inquires why a constant density n of ions per unit area is assumed as a criterion for the appearance of the discharge. This is a natural assumption. The ionization progresses with the voltage according to a high exponential law. The rate of increase with the applied voltage is definite and can be experimentally reproduced at will. This refers to experiments with steady potentials applied to plate electrodes. The phenomena is progressive until it becomes visible, and the ionization at *first* visibility is undoubtedly constant, at least for the same observer. This rapid rise of the ionization with the voltage has been found by all experimenters, and I would refer the reader to the numerous papers on this subject published during the last decade by Professor Townsend and his fellow workers. Professor Whitehead should have detected this partial ionization had his conditions been steady enough, and his detecting instruments of sufficient sensibility.

The origin of the constant $x_0 = 26{,}600$ volts per cm. is explained in the original paper. It was necessary to find an integrable equation that would agree with the theoretical expression (**7**) for the relation between, α, p and x. This integral equation is

$$\frac{\alpha}{p} = A + B\left(\frac{x}{p} - 350\right)^2$$

The number 350 is a constant, and on eliminating p from the

parenthesis, when p is expressed in centimeters of mercury, one obtains $76 \times 350 = 26{,}600$ for the value of x_0 at normal pressure.

The physical meaning of the constant x_0 is that ionization by impact will occur at all gradients greater than 26,600 volts per cm. and that one may neglect all ionization at gradients below that value. As a matter of fact, the kinetic theory of gases shows that some ionization by impact may occur at any gradient, however small.

Professor Whitehead also questions the experimental basis of the theoretical equation (**7**). Since the publication of the paper on the corona, I have compared equation (**7**) with all the experimental results obtainable for the relations between α, p and x. If one takes $v = 11.5$ volts, and the mean free path of an electron to be eight times that of a molecule, then equation (**7**) agrees with the experimental results with an accuracy of five per cent or better. The validity of this equation is thus supported by all of the experimental work on ionization by impact.

(2) The points made by Professor Bennett. It is not assumed that ionization will first be evident at that half cycle in which the electrons move towards the wire. Ionization by impact occurs when the electrons move outward as well as inward, but the *first* appearance of the visible corona will occur when the wire is on the positive phase. After the discharge is established, the ionization is very copious, and it probably occurs on both phases. That the discharge will occur when the wire is on the positive phase, is shown by the experiments of Prof. Townsend, (*Phil. Mag.*, April, 1914) who finds that for all pressures greater than 5 to 8 cm. of mercury, the discharge occurs at a less gradient for wire positive than when it is negative. The contrary is the case for smaller pressures. This theory is applied only at pressures greater than 5 cm. mercury. Professor Bennett's own experiments were made at 1 cm. pressure. He finds in this case that the discharge first occurs when the wire is negative. This also was observed by Professor Townsend. No matter whether the discharge occurs when the wire is positive or negative, the greater part of the ionization by impact is due to the negative ions.

Professor Bennett also has difficulty with the constancy of the left member of equation (**6**). The n_0 ions crossing Q inward are concentrated by the curvature. The geometry of the figure will show that the density of ionization will increase as the n_0 ions inward without ionization by impact. The numbers n and n_0 refer always to the number crossing unit area. Now if the total number of ions outside of Q is constant, then it is evident that the number n_0 crossing the surface Q will be less as b is larger. The surface of a cylinder is directly proportional to its radius.

The concentration due to curvature will be as b to a, and the value of n_0 will be inversely as b for any given case. That is, one is justified in assuming $\left(\frac{n}{n_0}\frac{b}{a}\right)$ to be approximately constant.

DISCUSSION ON "A MILLIAMPERE CURRENT TRANSFORMER" (BENNETT), WASHINGTON, D. C., APRIL 25, 1914. (SEE PROCEEDINGS FOR APRIL, 1914.)

(Subject to final revision for the Transactions.)

J. B. Whitehead (by letter): In conjunction with Professor Bennett's paper* last year at Cooperstown, the present paper completes a description of the equipment with which he has obtained his interesting and valuable results on the corona. The transformer which he describes, by offering a means for measuring the corona current, should open up a wide field of investigation. The possibility, as demonstrated by Professor Bennett, of neutralizing the charging current is especially valuable.

One or two questions suggest themselves:

As the scale of the diagram for Fig. 5 is evidently not the same for all vectors, I have not been able to understand the statements at the top of the following page.

The statement is made on the next page thereafter, under the heading "Phase Displacement and Ratio of Transformation," that the phase displacement and percentage reduction in the multiplier are proportional to the secondary resistance. I shall be glad to have further elucidation here.

Referring to Fig. 15, since presumably all the vibrators were in one oscillograph, the question of potential difference arises unless each vibrator was grounded.

J. R. Craighead (by letter): The specific features of design of a current transformer should be determined by the uses to which it is to be put. In Mr. Bennett's transformer, the primary winding is made of wire several times larger than would be needed on a heating basis, in order to keep the total impedance low. More accurate transformation of the current can be secured by using much smaller primary wire, thus increasing the ampere-turns or diminishing the mean length of magnetic circuit. This will be accompanied by an increase in the impedance and I^2R losses of the transformer which would be objectionable only for circuits of comparatively low voltage.

It should be emphasized that the current transformer is accurate only when carrying a true alternating current. When supplied with a current containing a direct-current component, it operates in a different range of flux density because of the constant magnetizing effect of the direct current, and the errors are largely increased. If a current transformer under normal conditions has from 2 to 5 per cent exciting current, the presence of a 50 per cent direct-current component therefore may readily give a direct magnetomotive force from 7 to 17 times as great as the maximum under operating conditions. Calculations of errors with alternating current alone cannot therefore be relied on to determine accuracy with pulsating

* "An Oscillograph Study of Corona", PROCEEDINGS A. I. E. E., June, 1913, page 1471.

currents. The alternating components of transients and rectified or partially rectified currents will not be accurately shown.

The alternative is the use of vibrators of higher current sensitivity. These are available of about 10 times the sensitivity of the standard vibrator, and consume about the same energy. This will cover satisfactorily many cases where the transformer would give inaccurate results, but will not reach to the extremely low values covered by the transformer.

Edward Bennett (by letter): With reference to the questions raised by Dr. Whitehead: In the vector diagram of Fig. 5 the exciting current I_e and its components I_m and I_w are drawn to ten times the scale of the primary and secondary currents. The voltage which must be generated by the magnetic flux in the iron, in order to set up the full load current through the secondary winding, will be directly proportional (approximately) to the total secondary resistance, since the reactance is negligible. The exciting current necessary in the primary to set up with magnetic flux will be approximately proportional to the flux and since the flux is proportional to the secondary resistance, therefore, the exciting current will be directly proportional (approximately) to the total secondary resistance. An inspection of the diagram will show that the exciting current will remain less than 5 per cent of the neutralizing current I_n for a reasonable variation in the secondary resistance. Under these conditions a study of the diagram will show that since the exciting current is directly proportional to the total secondary resistance, therefore "for small variations in the resistance of the secondary circuit, the angle of phase displacement and the percentage reduction in the multiplier will be approximately proportional to the secondary resistance."

In Fig. 15 the terminal of vibrator P is grounded and the vibrator S is ungrounded. One terminal of the primary of the current transformer to which the vibrator S is connected is grounded and the average potential of the primary from ground is less than 6 volts, therefore the potential of the vibrator S will probably differ from ground potential by less than 2 volts.

Mr. Craighead's comments apply more particularly to the characteristics of instrument transformers in which flux densities from 500 to 2000 lines per square centimeter are in use. In the milliampere current transformer, in which the maximum flux density is only 36 lines per square centimeter, we encounter features of design that are entirely negligible in the commercial transformer. For example, very little improvement indeed can be made in the characteristics of the milliampere transformer by increasing the number of turns in the winding:

First: Because the permeability decreases rapidly for flux densities below 50 lines per square centimeter so that very little is to be gained by using a lower flux density.

Second: Because an increase in the number of turns will increase to such an extent the component of the current which gets through the primary as displacement current from layer to layer, that high harmonics in the primary will not be faithfully reproduced.

Third: A material increase in the number of turns cannot be made without increasing either the length of the magnetic circuit or the resistance of the secondary.

Again, it would seem that the caution with reference to the use of the current transformer with pulsating currents can hardly be taken to imply that the oscillograms showing the presence of a large unidirectional component are appreciably in error. Even if the unidirectional component of the primary current exerted a magnetomotive force 17 times the exciting m.m.f., this would only lead to a unidirectional flux of 17 times 36, or 612 per square centimeter, on which would be superimposed a cyclic change of $\pm$ 36 lines per square centimeter. Under these conditions the wave form of the pulsating current would be faithfully reproduced in the secondary. As pointed out, however, in the paper, the wave form of the secondary current will, under these conditions, be so displaced with reference to the zero line as to make the average value of the secondary current zero.

Presented at the 299th meeting of the American Institute of Electrical Engineers, New York, October 9, 1914.

PROTECTIVE REACTORS FOR FEEDER CIRCUITS OF LARGE CITY POWER SYSTEMS*

BY JAMES LYMAN, LESLIE L. PERRY, AND A. M. ROSSMAN

ABSTRACT OF PAPER

This paper outlines the use and limitations of protective reactance coils in feeder circuits. When no feeder reactors are used, doubling up the station capacity increases the number and severity of short circuits. The insertion of feeder reactors cuts down the severity of a short circuit and practically renders the effect local, so that beyond a certain point additional generator capacity does not appreciably increase the severity.

Curves are given showing what the effects of feeder reactors are, with and without bus reactors, for generators of various reactances. The advantages that might be gained by parallel operation of feeders are discussed and the difficulties to be encountered are pointed out.

INTRODUCTION

IN a paper entitled "Protective Reactances in Large Power Stations" presented at the 1913 midwinter convention of the Institute, the authors discussed the use and limitations of current limiting reactors in generator circuits and in power station busbars.

It was shown in that paper that, on a radial feeder system, the use of busbar reactors tends to confine the disturbances from a short-circuited feeder to that section of the busbars to which the feeder is connected. It was also shown, in one example, that the use of 3 per cent feeder reactors reduced the amount of current flow into a feeder short circuit to 1/4 of what it would be without feeder reactors.

It is the purpose of this paper to discuss, in greater detail, the use and limitations of reactors in the feeder circuits of large city power stations.

The methods of deriving the curves of this paper are the same as are given in the appendix to our earlier paper. Where reference is made to maximum values this refers to maximum r.m.s. values and not to maximum instantaneous values.

*Manuscript of this paper was received May 20, 1914.

Transient effects are not taken into account by these curves. The transient effects can be derived from the r. m. s. values.

THE NEED OF FEEDER REACTANCES

Consider the case of a 225,000-kv-a. power station which generates electricity at 11,000 volts. Such a station would have, say, 80 feeders each rated at 5000 kv-a. If these feeders average three miles in length there would be a total of 240 miles of feeder cable installed. If on this system there are five break-downs per 100 miles per year, then there might be expected a total of 12 break-downs per year on the system, or an average of one break-down per month.

If the station capacity and the number of feeders are increased 50 per cent and the average length of feeder increases 33 1/3 per cent, then the break-downs will average two per month. If all of the feeder cables are tied directly to the power station busbars and no reactors are used in either feeders or busbars, heavy short circuits occurring within a mile or so of the power stations would be felt over the entire system, and might be felt with troublesome severity even when occurring at greater distances from the power station. At times of light load, few machines are running and the portion of the short circuit kilovolt-amperes carried by each machine on the system might easily be several times the normal load rating of each machine. Evidently one or two such general disturbances per month could not be tolerated. Properly designed feeder reactors limit the amount of short-circuit current in a feeder to such an extent that the effect is local.

CURVES

In order to study the effects of different values of feeder reactance a number of curves has been plotted.

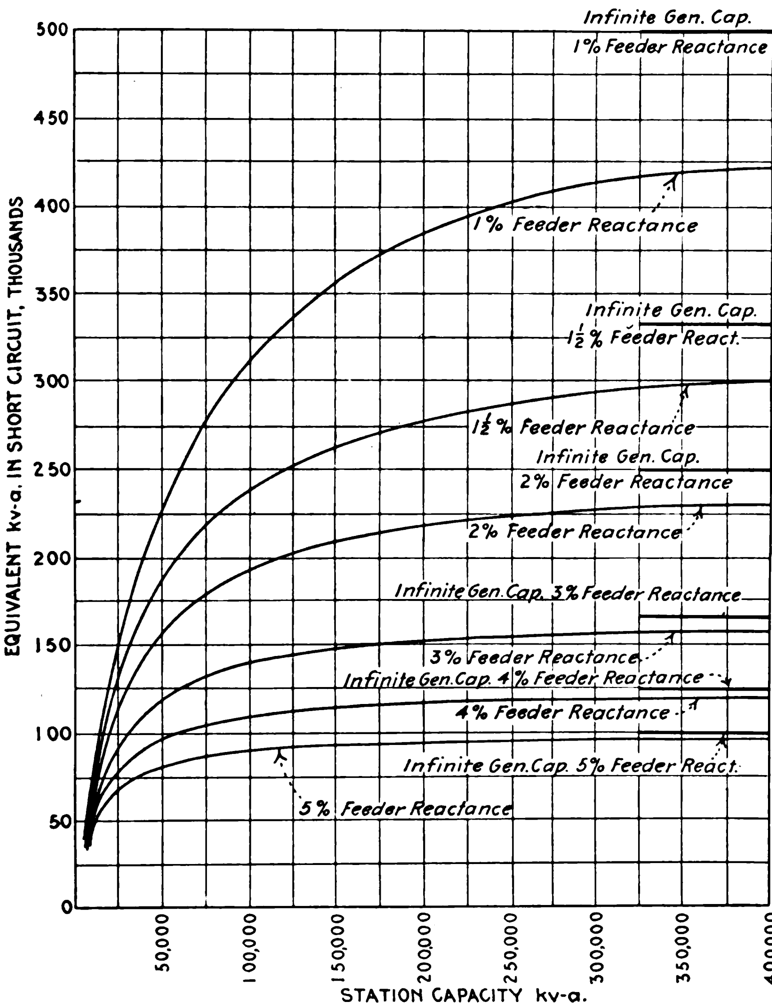
Curve sheet 1 shows the relation between the equivalent kilovolt-amperes in a short circuit and the station capacity in kilovolt-amperes for six different values of feeder reactance when no bus reactance is used. The generators in this case have 12 per cent inherent reactance.

Curve Sheets 2 and 3 show similar sets of curves which differ from the curves on Curve Sheet 1 only in the values of inherent generator reactance, which are chosen at 10 per cent and 8 per cent respectively.

The points of special interest shown by these curves are:

(a) With infinite generator capacity the equivalent kilovolt-

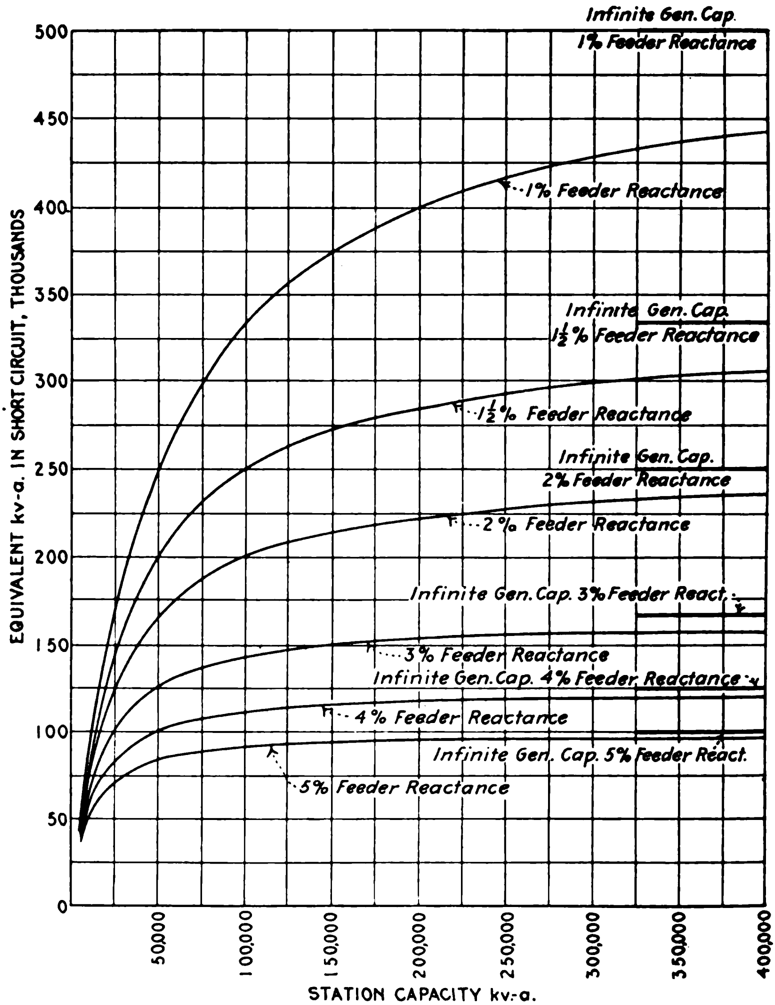
amperes in a short circuit vary inversely as the reactance in the feeder circuit.



Curve Sheet No. 1—Curves Showing Values of Short Circuits in Terms of Kv-a. with Feeder Reactors of Various Per Cents—Inherent Generator Reactance 12 Per Cent without Bus Reactors—5000-Kv-a. Feeders.

(b) The equivalent kilovolt-amperes in a short circuit with infinite generator capacity are the same for the three sheets of curves.

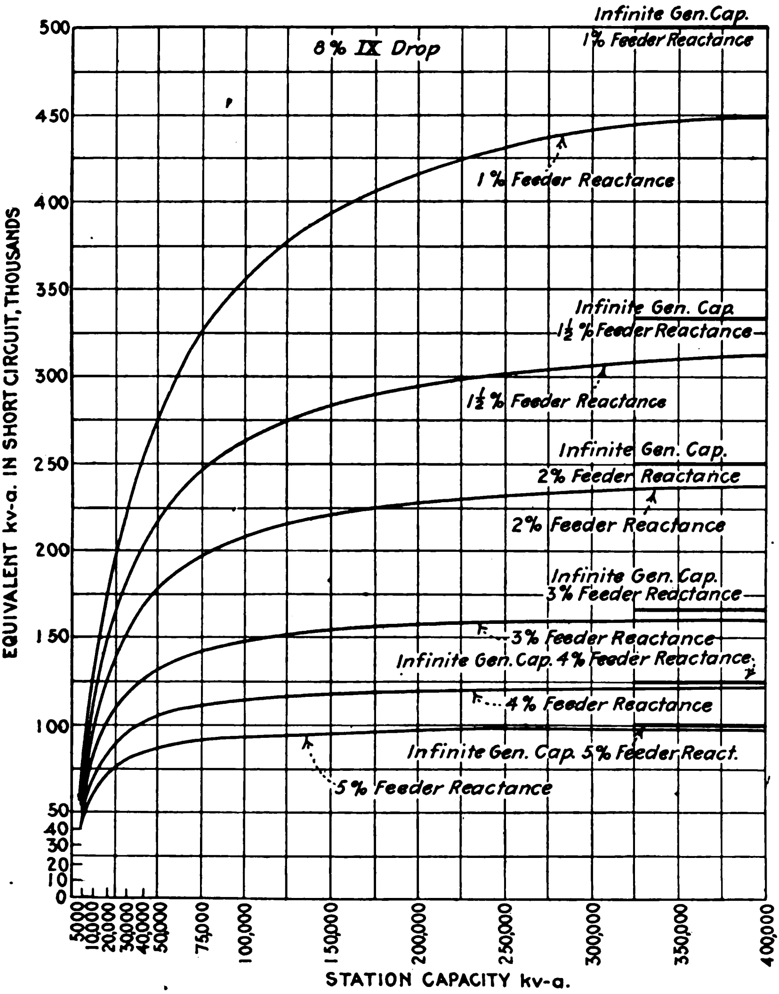
(c) The kilovolt-amperes in short circuit increase more rapidly per kilovolt-ampere of station capacity for a small station than for a large one.



Curve Sheet No. 2—Curves Showing Values of Short Circuits in Terms of Kv-a. with Feeder Reactors of Various Per Cents—Inherent Generator Reactance 10 Per Cent without Bus Reactors—5000 Kv-a. Feeders.

A comparison of similar curves on the three sheets shows that the variation in generator reactance does not greatly affect the curves. Curve Sheet 4 shows the four curves for 3 per cent (of

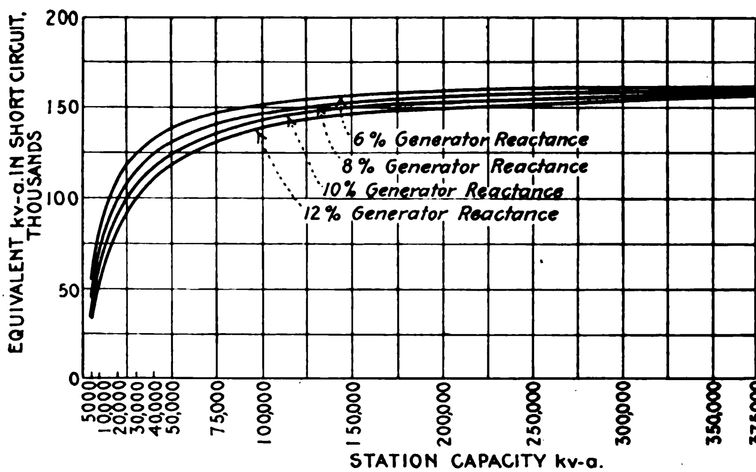
5000 kv-a.) feeder reactance replotted on the same sheet for generator reactance of 12 per cent, 10 per cent, 8 per cent and 6 per cent, respectively. By comparing the curve for 6 per cent



CURVE SHEET NO. 3—CURVES SHOWING VALUES OF SHORT CIRCUITS IN TERMS OF KV-A. WITH FEEDER REACTORS OF VARIOUS PER CENTS—INHERENT GENERATOR REACTANCE 8 PER CENT WITHOUT BUS REACTORS; 5000 KV-A. FEEDERS.

generator reactance with that for 12 per cent generator reactance the small effect of the generator reactance on the curves is evident.

Curve Sheet 5 shows the relation between equivalent kilovolt-amperes in a short circuit and station capacity in kilovolt-ampere with 10 per cent generator reactance and 3 per cent (of 5000 kv-a.) feeder reactors under two conditions. Under one condition no bus reactors are used. Under the other condition 12 per cent (of 25,000 kv-a.) bus reactors are used. The points of interest here are, that where 12 per cent bus reactors and 3 per cent feeder reactances are used, the equivalent kilovolt-amperes in a feeder short circuit becomes practically constant at 125,000 kilovolt-ampere station capacity, and any further increase in station capacity has no appreciable effect in increas-

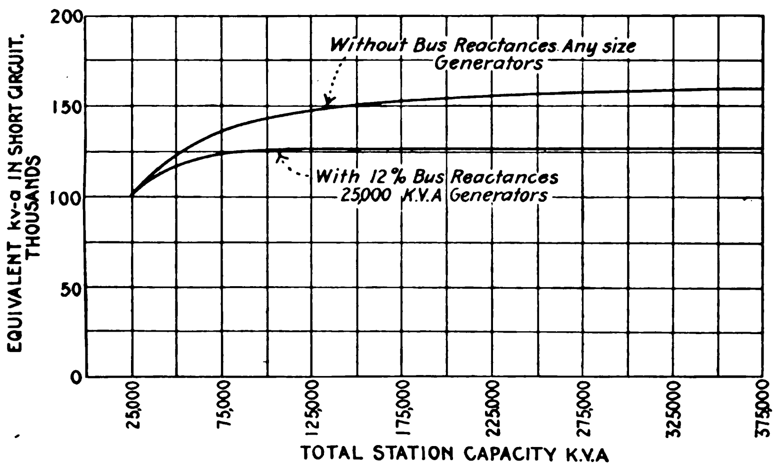


CURVE SHEET No. 4—CURVES SHOWING VALUES OF SHORT CIRCUITS IN TERMS OF KV-A. WITH 3 PER CENT FEEDER REACTORS AND VARIOUS GENERATOR REACTANCES WITHOUT BUS REACTORS—THREE-PHASE SHORT CIRCUITS—5000 KV-A. FEEDERS.

ing the short-circuit kilovolt-amperes. Where no busbar reactors, but 3 per cent feeder reactors are used, the short-circuit kilovolt-amperes increase until with infinite generating capacity they become 167,000 kilovolt-amperes.

Interpreted in another way, when the busbar reactors are used the feeder reactors absorb 75 per cent of the voltage and therefore give a 25 per cent drop in voltage on the section of the busbars to which the feeder is connected under the worst conditions of short circuit. This means that all of the feeders connected to that section will suffer a momentary d op in voltage of 25 per cent. Where no busbar reactors are used, the feeder reactor

on the defective feeder will, under the worst conditions, absorb 100 per cent of the voltage and will pass 40,000 more kilovolt-amperes, but the voltage of the other feeders on the system will not be appreciably affected. If there were no possibility of a short circuit on the busbars or between the busbars and the feeder reactors and no possibility of a failure of the generator windings or connections between windings and busbars, it is evident that the use of feeder reactors alone is preferable to the combination of feeder reactors and bus-bar reactors, but with these live possibilities of trouble always present, busbar reactors should be considered. Whether or not they should



CURVE SHEET NO. 5—CURVES SHOWING VALUES OF SHORT CIRCUITS IN TERMS OF KV-A. WITH 3 PER CENT FEEDER REACTANCES, 10 PER CENT GENERATOR REACTANCES—WITH AND WITHOUT 12 PER CENT BUS REACTANCES—5000-KV-A. FEEDERS.

Bus reactance rating based on 25,000 kv-a. Bus reactances located between adjacent generating capacities of 25,000 kv-a.

be adopted depends upon the particular conditions of the system under consideration. It is evident that a very large power station without either bus reactors or feeder reactors is liable to short circuits which will endanger apparatus and service, due to the practically unlimited concentration of power in the short circuits.

EFFECT OF FEEDER REACTORS ON VOLTAGE REGULATION

At 0.8 power factor a 3 per cent feeder reactor will cause a voltage drop of approximately 1.8 per cent, at 0.9 power factor, a drop of approximately 1.3 per cent, at 0.95 power factor a

drop of approximately 1.0 per cent, and at 0.98 power factor a drop of approximately 0.6 per cent.

In large city power stations such as have been considered, there is always a considerable amount of synchronous apparatus in operation at a high power factor and the voltage drop due to 3 per cent reactance in their feeders will be low.

The Parallel Operation of Feeders

The paralleling of a-c. feeders on a set of busbars at the substation end and the tying together of the different substation buses by means of tie feeders between substations would be highly desirable on most of our large city systems, if it could be safely accomplished. Such a method of operation would allow maximum facility in the interchange of power between various parts of the system, with a minimum amount of cable; the cables between the power station and each substation would be more evenly loaded and the total number of cables could be reduced. Because of the cables between substations, the necessity of idle reserve cables between power station and substations would be eliminated. During the period of peak load on a given substation, power would flow in over the tie cables from substations not carrying their maximum loads; and later when the conditions of peak were reversed the flow of power would be reversed.

The Effect of Reactance Coils on the Parallel Operation of Feeders

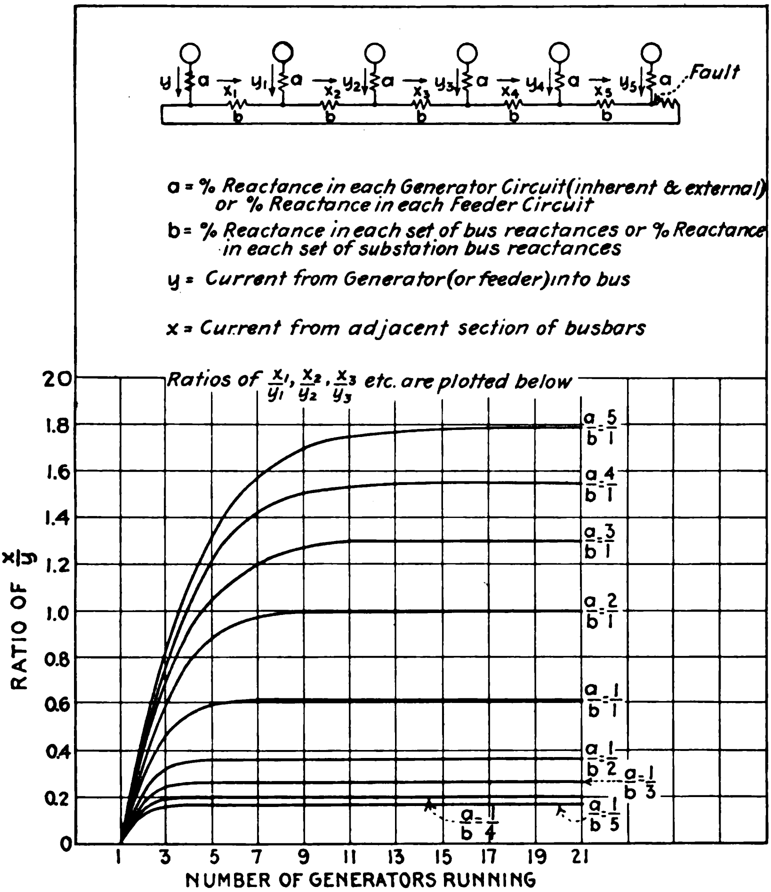
To assist in the study of the amount of short-circuit current which can flow into a fault, the series of curves on Curve Sheet 6 was plotted. These curves can be applied to approximate the amount of short-circuit current into a fault on the busbars of a power station where busbar reactors are used, or to approximate the amount of short circuit current into a fault on or near the substation busbars where several feeder cables are connected in parallel on the substation busbars with busbar reactors between them.

As applied to the case of a power station, one or two examples will be cited. Assume the case where the ratio of generator reactance to busbar reactance (a/b) equals 1/3. The corresponding curve is almost constant with three running generators. This means a short circuit on any section of the busbars is practically maximum when the generator on the same section and one generator on each adjacent section are in operation, and the addition of more generators to the system will not appreciably increase the amount of short-circuit current.

Where the busbar reactance and generator reactance are equal ($a/b = 1/1$) the maximum value of current is nearly reached with five generators running.

In applying the curves to a substation consider the following concrete example:

Consider a case in which the inherent reactance in each feeder



CURVE SHEET No. 6

equals 1 per cent, artificial reactance equals 3 per cent, and bus reactance equals 3 per cent, all based on 5000 kilovolt-amperes. Then if a short circuit occurs on or near the substation busbars the kilovolt-amperes flowing in over the short-circuited line equal $\frac{5000}{0.04}$, or 125,000 kv-a. $a/b = 4/3 = 1.33$. From curves, by

interpolation, $x/y = 0.75$. Hence, the kilovolt-amperes flowing over each adjacent bus reactor equal $0.75 \times 125{,}000 = 93{,}750$ kv-a. and the total kilovolt-amperes flowing into the fault $= 125{,}000$ kv-a. $+ 2 \times 93{,}750$ kv-a. $= 312{,}500$ kv-a.

The 93,750 kv-a. flowing in over each bus reactor are composed of two components, one flowing in over the second reactor and the other over the adjacent line. These also bear the relation to each other of x/y ($= 0.75$). Hence, over the second reactor there flow in 40,180 kv-a. and over the adjacent feeder 53,570 kv-a.

In this case with 125,000 kv-a. flowing into the fault from the feeder on the same section with the fault, and 53,570 kv-a. over each adjacent feeder, it is probable that all three of these feeders will go out at once and these will be followed by the other feeders in the substation.

Consider another case in which the total reactance in the feeder is as high as 10 per cent, and the bus reactance is also 10 per cent. (Both based on 5000 kv-a.). Then, in case of a short circuit on or near the substation busbars, the kilovolt-amperes flowing in over the line equals $\frac{5000}{0.10}$ or 50,000 kv-a. $a/b = 1$. From the curve, $x/y = 0.62$. Hence, kilovolt-amperes flowing over each adjacent bus reactor $= 0.62 \times 50{,}000 = 31{,}000$, and the total kilovolt-amperes flowing into the fault $= 50{,}000 + 2 \times 31{,}000 = 112{,}000$ kv-a.

The 31,000 kv-a. flowing in over each bus reactor are composed of x and y components bearing the relation $x/y = 0.62$. Hence, over the second reactance there flow in 11,850 kv-a. and over the adjacent feeder, 19,150 kv-a.

In this second case 50,000 kv-a. flow in over the feeder connected to the faulty section of the busbars, while 19,150 kv-a. flow in over the adjacent feeders. It is therefore probable that with the ordinary relay setting, all three of these feeders will go out at nearly the same time and that these will be followed by others. Furthermore, such large reactors in feeders and substation busbars would have a serious effect on the voltage regulation of the system, and would in a large measure defeat the purpose of their installation, viz., to permit the free interchange of power between different parts of the system.

Another arrangement of feeder reactors would be to place reactors at both ends of the feeders and omit the reactors

from the substation busbars. This scheme would be more objectionable than the one discussed above, because a short circuit on the substation busbars would be fed by the several feeders in parallel, and, if these feeder circuits were all alike, the kilovolt-amperes flowing into such a short circuit would be directly proportional to the number of feeders connected to the substation busbars.

Several power stations of about 50,000-kv-a. generating capacity are operating today with feeders tied together at the substation end. In several of these stations it has been noticed that a severe feeder short circuit usually trips out several feeder switches and sometimes causes a general interruption to service.

The above analyses show that even on feeders from a very large generating station, feeder reactors of moderate size effectively limit the amount of current flowing from the power station end into a short circuit on the feeder. On the other hand if this feeder is one of a number of feeders connected in parallel at the substation end, a short circuit will have a back feed from all of the other feeders connected to the substation busbars. The amount of kilovolt-amperes flowing over these other parallel feeders is likely to be sufficient to trip out part or all of the oil switches on these circuits.

Summary

In a large city power system, the miles of underground cable and consequently the cable faults increase at a faster rate than the generating capacity. The severity of short circuits also increases with increased generating capacity. Feeder reactors are particularly effective in reducing and localizing the effect of such short circuits. When properly proportioned feeder reactors are used, an increase or decrease of generator reactance has only a limited effect on the amount of kilovolt-amperes flowing into a fault. Bus section reactors in the generating station in connection with feeder reactors still further reduce and localize these effects, even when it might be more desirable to distribute their effect if other conditions permitted.

It would be desirable for many reasons to operate feeders in parallel at their substation ends, but such operation tends to increase greatly the kilovolt-amperes flowing into a feeder short circuit and to cause other feeders besides the one affected to trip out when overload relays with the usual settings are used.

Presented at the 299th meeting of the American Institute of Electrical Engineers, New York, October 9, 1914.

USE OF REACTANCE WITH SYNCHRONOUS CONVERTERS

AN INSURANCE TO CONTINUITY OF SERVICE AND A PROTECTION TO APPARATUS

BY J. L. MCK. YARDLEY

ABSTRACT OF PAPER

The paper presents the results of overload and short-circuit tests made several years ago upon some synchronous converters in circuit with auxiliary reactors.

Two entirely separate sets of tests upon two synchronous converters of widely different operating characteristics are described. In the one case the reactor is in the a-c. circuit and in the other in the d-c. circuit; yet in each it may be called, and in fact is, a protective reactor.

In presenting this original information the author, with a view to indicating its commercial application and hoping to provoke discussion, has endeavored to divide synchronous converter installations in a general way into classes with respect to the need or desirability of employing protective reactance, and also with respect to the general design or type of the reactor to be employed. In order to do this, synchronous converter installations are divided into a few general classes with respect to the character and exactions of the service conditions under which they are required to operate.

The paper was written shortly after the tests were made, but although much has been learned or written about protective reactors since that date, the author believes nothing has transpired to affect the value of these tests or to make it necessary to change the form in which it was originally intended to present them.

SYNCHRONOUS converter installations considered with regard to the relative importance of service and apparatus may be divided into three classes:

1. Installations where it is of prime importance to keep voltage on the lines at all times.

2. Installations where heavy overloads are frequent but where, to protect apparatus and accordingly maintain service, the voltage may be allowed to drop off during the overload.

3. Installations where high momentary overloads are frequent, unattended by appreciable voltage drop, but where brief even though comparatively frequent interruptions to service are not objectionable in order to protect apparatus.

Installations of the first class are found feeding the network

of circuits forming the distribution system of a metropolitan lighting and power company. Here the aggregate of power handled is the largest found in any power systems. The generating, transforming and converting stations are of the largest and most highly concentrated. The customers are the most numerous and the most widely distributed. The service required is the most varied in quality and quantity.

In such a system, handling an enormous aggregate of power, there is a large demand for service every hour of the twenty-four, every day in the year. Any failure, of however brief duration, to supply this demand means a great aggregate loss to the customer in money and convenience. In such a system, where immense quantities of power are generated in a concentrated generating station or group of stations, passed out through diverging feeders, transformed and converted in a plurality of substations and finally delivered 24 hours per day through a multiplicity of circuits to the ultimate consumer, the secret of satisfactory service lies in the smooth and orderly working of the various parts of the system. The difficulties in the way of securing uniform operation of such a quantity and variety of apparatus have been overcome only through great engineering skill. The method of operation is carefully prearranged and the various pieces of apparatus are started and stopped according to a schedule so as to make the service continuous. It is a tremendous undertaking to start and place in normal operating condition all the apparatus on the system when once it has been shut down. The utmost perfection of cooperation between men is required. A very severe strain is placed upon the power company's apparatus, while the delay and loss to the consumer incident to interruption is absolutely prohibitive. It becomes, therefore, a matter of necessity to maintain voltage on the customers' circuits at all times.

The direct-current feeders are interconnected at many points. A short circuit or ground on one feeder would trip out the overload breakers at a number of stations and thereby completely remove voltage from a comparatively large section of network. It is, therefore, considered preferable to omit automatic tripping features in the d-c. feeders. A short circuit or ground must, therefore, burn itself free or be eliminated only by some of the a-c. circuit breakers or apparatus letting go. In some of the very largest systems, the current-carrying capacity of the largest feeder is so small compared to the momentary overload capacity of the feeders to which it is tied, and of the apparatus supplying

them, that the trouble almost immediately clears itself. The total voltage is available at the scene of trouble. An arc of such magnitude is formed in consuming this voltage that the trouble shortly burns through. The voltage being consumed in the feeder having the fault, the remaining feeders continue supplied with scarcely reduced voltage and the apparatus running from them is scarcely affected. In these systems the trouble clears itself without seriously overloading the substation apparatus. In case the trouble should exist in the immediate vicinity of a substation so that substation would tend to carry the entire trouble, that substation would be saved from damage by the tripping out at the generating station of the a-c. supply feeders. The trouble would then, if it lasted long enough, be thrown on the remaining substations, which would more or less equalize it, and on account of their great capacity would be able to carry it until it cleared itself. There is, accordingly, no need of protective reactance in a substation of this character.

In systems of this general character but of somewhat smaller dimensions the current capacity of the largest feeder bears a less desirable ratio to the overload capacity of the feeders and apparatus supplying it. There are three immediate results:

(a) The trouble does not clear so quickly, as the current at the reduced voltage available at the trouble is not so great.

(b) The voltage on the other feeders falls off appreciably from the normal condition. Lights dim and motors slow down, but, in general, all apparatus continues to operate and a general shut-down does not result. The apparatus on the particular feeder in trouble probably stops owing to the greatly reduced voltage.

(c) Greater momentary overloads are thrown on all the supply apparatus. It is important, therefore, to give the apparatus characteristics such as to enable it to withstand these overloads satisfactorily.

The converting apparatus is usually a synchronous converter, though in some installations motor-generator sets are employed. These motor-generator sets have not the momentary overload kilowatt capacity of the converter. Usually the motor will pull out of step before the generator is dangerously overloaded. The synchronous converter will, in general, carry several times more kilowatt load than the motor-generator set before dropping out of step. It will carry so much overload before failing in this respect that the effect upon commutation must be considered. In the case of a shunt-wound motor-generator set, owing to the

poor voltage regulation of the generator, the current which can be commutated before the motor pulls out approaches more nearly the value of current which can be commutated by the converter. Some tests which will be given later on show that it is possible to throw six times normal full load current on some converters before they will flash over. It is obvious, however, that the actual possible limit of the converter is not the limit which must be observed in a commercial case. Assuming, therefore, that the converter will carry 400 per cent normal load current for a time comparable to that required for d-c. line trouble to burn itself free, it remains to equip the converter with auxiliaries which will enable it to escape all load in excess of this amount. There are several ways in which this may be accomplished when it is first known how much the voltage must be reduced.

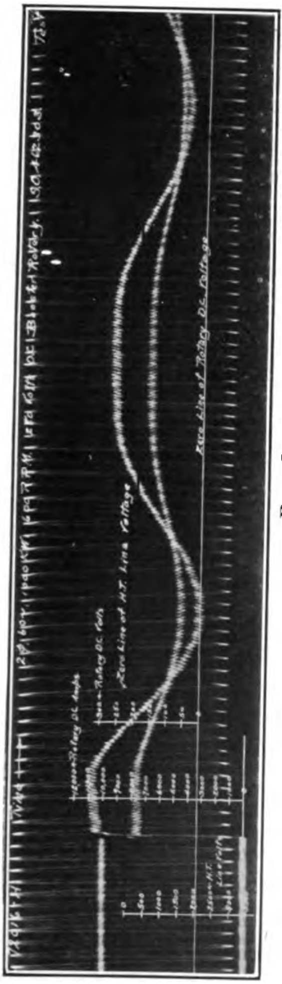
1. In the case of a booster or split pole converter the voltage can be lowered to the full buck value at any desired overload by means of relays in the d-c. circuit actuating the voltage controlling element of the converter. On account of the time element of the relays and rheostat and the magnetic lag in the iron circuit of the converter this method is probably not quick enough.

2. A resistance short-circuited by a circuit breaker may be placed in the d-c. lead. The breaker would be tripped at some fixed value of current and the resistance placed directly in circuit. Owing to the time element of the ordinary overload circuit breaker this method is probably not quick enough.

3. With reactance placed in the a-c. circuit, a series field can be added to the main poles acting in opposition to the shunt winding, so that the power factor becomes badly lagging on overloads and the reactance produces a drop in voltage. This involves a series field on the converter, and the overload capacity of the converter is further limited by the wattless armature currents caused by the overload current in the series field.

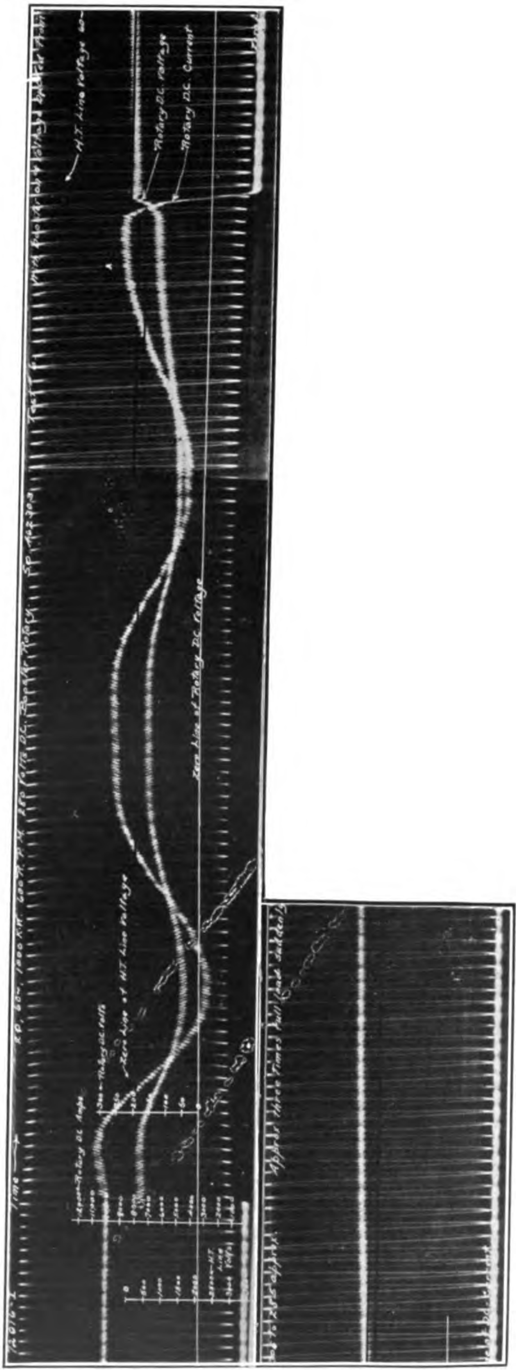
4. A larger amount of permanent reactance may be placed in the a-c. circuit so that, even with a shunt-wound converter and approximately constant power factor, a great drop in voltage will occur at large overloads.

The fundamental objection which has been raised to apply to this last method as well as to the other methods suggested is that, owing to the inertia of the rotating part, the synchronous converter, in common with the direct-current generator, delivers an instantaneous direct current when the resistance of the external d-c. circuit is suddenly reduced, which can not be reduced



[YARDLEY]

FIG. 2



[YARDLEY]

FIG. 3

PLATE CII
A. I. E. E.
VOL. XXXIII, NO. 11

[YARDLEY]

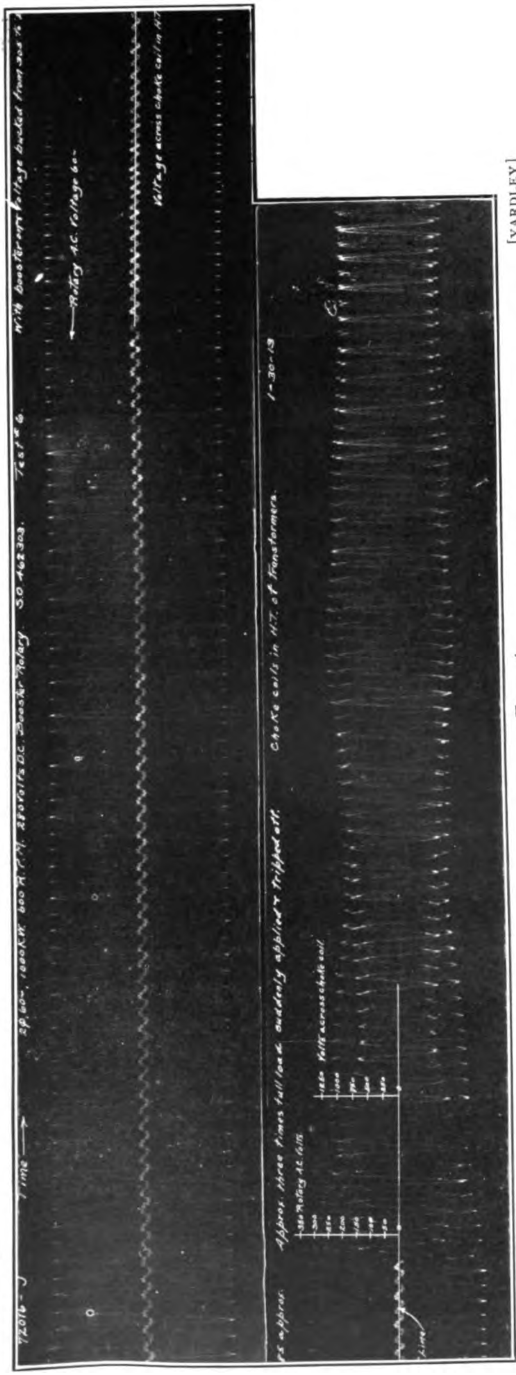


FIG. 4

[YARDLEY]

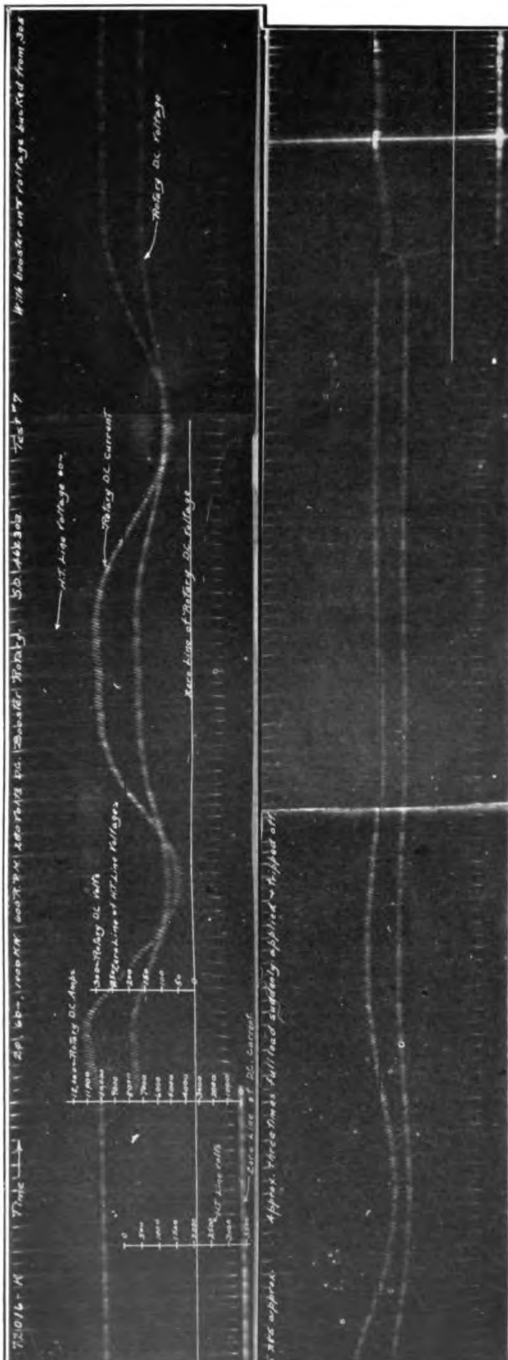


FIG. 5

[YARDLEY]

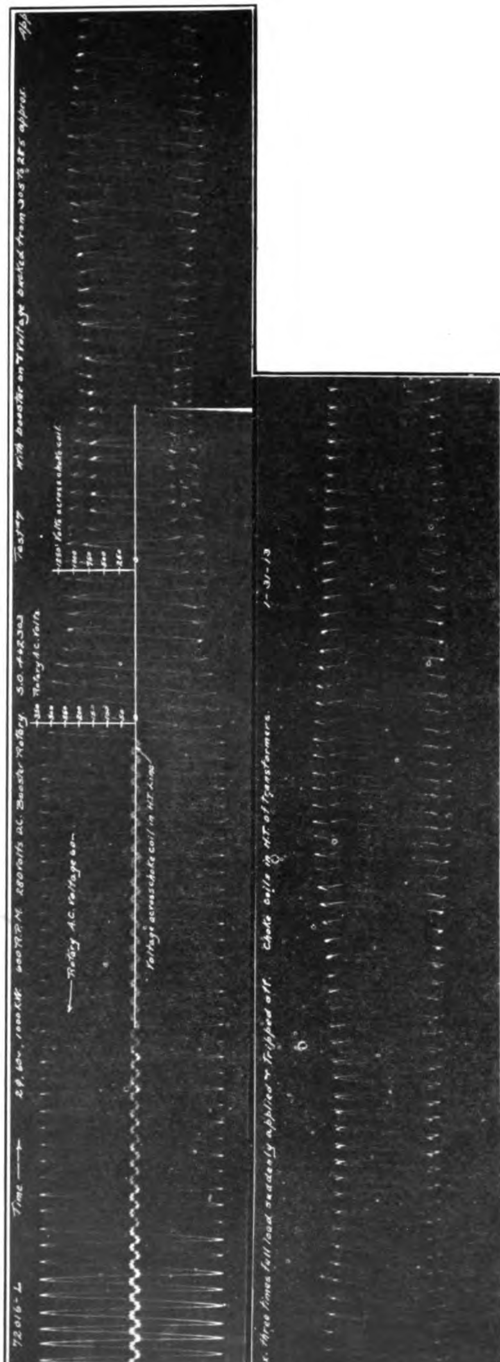
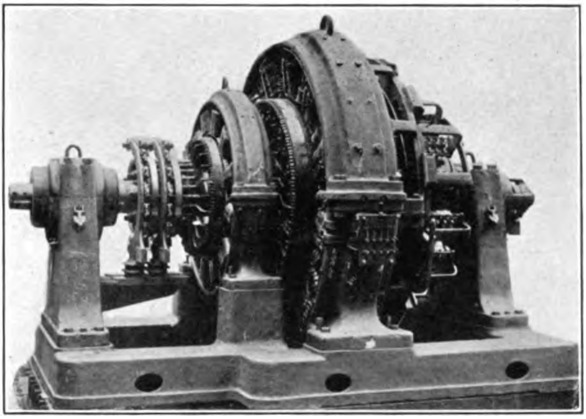
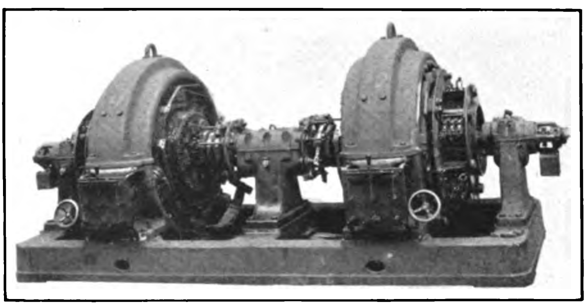


Fig. 6



[YARDLEY]

FIG. 7—280-VOLT, 1000-KW., 60-CYCLE COMMUTATING-POLE SYNCHRONOUS CONVERTER



[YARDLEY]

FIG. 10—TWO 750-VOLT, 60-CYCLE SYNCHRONOUS CONVERTERS CONNECTED IN SERIES

by any of the means suggested and which, particularly in the case of the converter, is likely seriously to affect the commutation.

Without debating this question, it is proposed to state that with a reactor of the air-core or unsaturated type in the a-c. circuit, there is no question but that the voltage drop across the reactor will follow instantaneously and exactly the alternating current variations. It follows that, if the alternating current is at all times approximately proportioned to the direct current, a reactor may be employed in the a-c. circuit to limit the overload current which the converter can deliver.

Assuming a reactor of 30 per cent, the voltage impressed at the collector rings under several conditions of load is shown by the side A in the triangles of Fig. 1. The effect of the varying reactive drop B is to vary the phase angle of the voltage impressed at the collector rings. The converter must therefore be well equip-

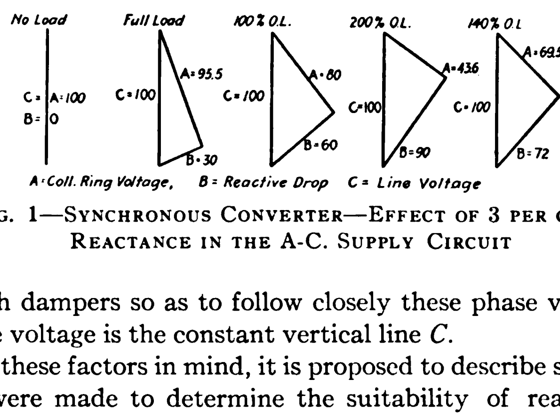


FIG. 1—SYNCHRONOUS CONVERTER—EFFECT OF 3 PER CENT REACTANCE IN THE A-C. SUPPLY CIRCUIT

ped with dampers so as to follow closely these phase variations. The line voltage is the constant vertical line C.

With these factors in mind, it is proposed to describe some tests which were made to determine the suitability of reactors for such service in connection with a converter under a certain set of known conditions.

A certain 250-volt three-wire Edison system enjoying the enviable record of having maintained voltage on the bus over a long period of years was the subject of this study. Ordinary feeder troubles have drawn the substation bus voltage down to 180 volts or 200 volts. In one or two cases of very severe trouble the bus voltage has been drawn down to approximately 160 volts, that is, to 64 per cent of normal, before the trouble cleared itself without a general shut-down. The amount of reactance required, therefore, for a converter on this system is such as will draw down converter voltage to 64 per cent of normal before the overload exceeds the limits of the converter.

A 250-volt converter was not available, but a 280-volt, 1000-kw., two-phase, 60-cycle, 600-rev. per min. commutating-pole booster converter with voltage range of from 240 to 320 d-c. was available. This converter was wired up to a bank of three-phase-two-phase transformers, in the circuit to which were placed three air-core reactors. The converter was loaded on rack resistors. The load was thrown on by closing a knife switch and was tripped off by means of a d-c. circuit breaker. One element of the oscillograph was arranged to show the voltage of the a-c. supply circuit outside of the reactance coils, for the purpose of showing that to a large degree the reduction of the d-c. voltage came about independently of any reduction in the voltage of the supply circuit. The other two elements of the oscillograph were arranged to show the direct current and voltage, which are the quantities of particular interest in determining the effect of the reactance. There was

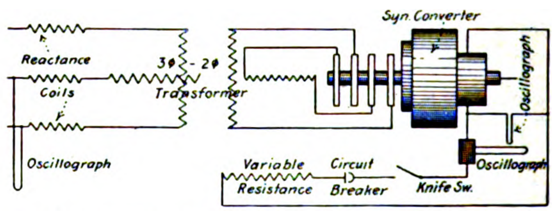


FIG. 8—CONNECTIONS FOR CURRENT-LIMITING REACTANCE

approximately 30 per cent reactance in the circuit in coils and transformer. There was a drop of not more than 5 per cent in the line voltage; but, due to the reactance and a large resistance drop in the converter, transformers and leads, the converter direct voltage at 8600 amperes output—that is at 2.4 normal load—was reduced 50 per cent, to 140 volts. See Figs. 2, 3 and 5. Figs. 4. and 6 show the record of a second oscillograph. Fig. 4 was taken simultaneously with Fig. 3, and Fig. 6 with Fig. 5. They show the low-tension voltage at the collector rings and the voltage across the reactance coil in the high-tension circuit. Fig. 5 was taken to see if the hunting would dampen out, and the load was held a total of 8 4/5 seconds, which is much longer than the average line trouble takes to clear itself.

The synchronous converter employed was provided with relatively inefficient dampers, and there was marked hunting at approximately 80 alternations per minute when load was first thrown on, owing to the shift in phase angle of the voltage im-

pressed at the collector rings. There was severe sparking at intervals corresponding to the period of hunting, which practically died out as the hunting ceased. The sparking was not so severe but that the load might very probably have been further increased or the reactance reduced, without exceeding the flashing limitations of the converter even with its ineffective dampers. This hunting and sparking would have been greatly reduced and possibly entirely eliminated if the converter had been provided with a damping winding of better design. There was no appreciable instantaneous d-c. generator effect, as the circuit was closed, which could be separated from the hunting action and the tests were considered by a large number of engineers who witnessed them to show very conclusively the value of reactance used in such an application.

2. The substations on large or medium size interurban railway systems are in the class of installations which are subject to heavy overloads, where it is, in general, satisfactory that the voltage on the lines shall drop off and vary considerably during the overloads in order that the supply apparatus may be protected from injury. The size of the individual piece of converting apparatus is small compared to the capacity of the transmission system of trolley wires and feeders, though it is still large compared to the maximum momentary overload likely to be thrown on it. This is owing to the number of converter substations which will be in parallel and will divide any abnormal overload. In the case of a short circuit or ground on a d-c. feeder, there is great likelihood that the trouble will burn itself free as in the first class of systems, the capacity of a single feeder or trolley wire being small, relative to the size of the whole system.

These systems are large enough to have carefully worked out train schedules and to require close adherence thereto. Uniformity of trolley voltage is therefore an important requisite and the supply apparatus is given a voltage characteristic which continues to rise for all moderate overloads. In many cases compound-wound converters with suitably chosen series field and reactance are employed.

With a shunt-wound converter considerable voltage variation would be experienced unless the a-c. and d-c. reactance and resistance drops should happen to be quite small. With considerable series field and unsaturated reactor, a converter would continue to take on load owing to its approximate straight-line rising voltage characteristics, and some means must be supplied to pre-

vent this load from reaching a value under abnormal conditions which would be injurious to the converter. There are disadvantages in having this protection in the form of a circuit breaker, since such a form of relief simply throws a greater over-load upon the remaining converters on the system when one trips, and a general shut-down may result. It is much preferable to have the converters in each substation protected in such a manner that, in case a short circuit, grounded feeder, or abnormal load due to the bunching of cars occurs at any point of the system, the converters in the immediate vicinity will continue on the line carrying all the overload they are able to carry. By providing a voltage characteristic which will droop before the critical safe overload is reached, the excess load is automatically distributed among the converters elsewhere on the system without actual interruption of service or drop in trolley voltage such as need affect the time schedule. The drooping characteristic on overload is obtained by employing a saturating iron-core reactor. Iron-core reactors have been installed in some of the largest substations in the country to equalize the load between transformer synchronous converter units having different inherent regulation characteristics. The use of them to divide the load between the different substations of a system, and by the voltage drop they produce thus protect the individual substation apparatus from injury, thereby tending to secure continuity of service, is therefore but a wider application of the well-known functions of a well-known piece of apparatus.

3. The substations on small and medium size interurban railway systems are in the third class of installations. One converter supplies a comparatively long section of trolley line on which there are a comparatively small number of cars running at relatively long intervals. The drop in trolley line and feeder to points distant from a substation is considerable. Additional drop in reactance would be objectionable under normal operating conditions. The converter should have a rising voltage characteristic, therefore, to take care of the normal operating conditions. It must, however, have some protection from d-c. short circuits and abnormal overloads, particularly when these occur close to a substation. The overloads have a maximum so much greater than the average load and are, relatively, so infrequent that neither of the two previous methods of protection is best adapted. In this case it is necessary actually to get the converter off the line to prevent damage. The bigger the momentary

overload which can be carried before tripping off, the better, but momentary interruptions are not serious (particularly as in such a system the feeders and trolley wires are usually sectionalized so that a trip out at one substation does not mean an interruption on the whole system) and the converter *must* be protected, at a temporary expense to service if necessary.

There is a limit to the current which any commutating machine will commutate without flashing over. This limit of instantaneous commutating capacity is usually way above the permissible capacity for any appreciable time limited by armature heating. The breaker may then be set considerably above any guaranteed overload value on such a system as we are now discussing, where the overloads, though very great, are very brief. A converter will also usually carry a much greater load momentarily than it will permit to be tripped off without flashing. Now there are certain auxiliaries which will greatly increase the severity of the short circuit to which the converter may be subjected without feeling it. If it is possible to throw overloads of five to six times normal on a converter before it will flash, the auxiliaries must prevent any excess beyond that amount. These auxiliaries consist of a reactor to introduce a time element in the rise of current when the short circuit is established, and a quick-acting circuit breaker. These two must be proportioned so that the trouble will be cleared before the current has reached a value which the converter can not safely commutate nor stand being tripped off. The reactance must be of the air core or unsaturated type and the breaker must necessarily be quite different from the ordinary d-c. carbon circuit breaker which has a very appreciable time element.

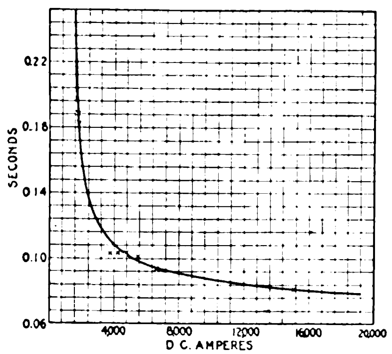


FIG. 9—TIME OF OPENING OF 1600-AMPERE, 600-VOLT CIRCUIT BREAKER

The ordinary carbon type d-c. circuit breaker has a time element which would require a prohibitive amount of reactance. Curve Fig. 9 gives the time element of an ordinary circuit breaker of 1600 amperes capacity. This gives the time for the mechanical operation only. Figs. 12-15 show the time taken by such a breaker to open the circuit.

The high-speed circuit interrupter as developed by Messrs. Fortescue and Mahoney consists essentially of an ordinary single-pole breaker, the parts of which are accelerated by means of a heavy steel spring. After the spring has ceased accelerating the momentum of the moving parts is gradually absorbed by means of a dash pot, so that the mechanism is not injured by sudden stopping. The breaker is provided with magnetic blowouts and a special condenser-operated tripping device, the moving parts of which are designed to have a minimum of friction and moment of inertia.

The operation of the tripping device depends upon well known characteristics of a direct-current circuit, as follows: Under steady conditions of load the only resistance offered to the flow of current is the ohmic resistance of the conductor. If the circuit were absolutely non-inductive, current changes due to change of resistance would take place at an infinite rate, but due to the fact that inductance is always present in any circuit, the current takes an appreciable time to reach a definite value. This is due to the e.m.f. set up by the inductance which is proportional to the rate of change of the current, and is in opposition to the impressed e.m.f. of the circuit. Thus if I_0 be the current in a circuit whose resistance is R_0, if the resistance of the circuit be suddenly changed to R_1, the e.m.f. of self-induction must be equal at the instant of change to $I_0\ (R_0 - R_1)$. The back e.m.f. of self-induction is therefore in a measure proportional to the severity of the short circuit. If a condenser connected in series with an electromagnet be shunted across the circuit, when the sudden overload or short circuit takes place there will be a drop in the e. m. f. across the condenser due to the inductance of the lines between the source of e. m. f. and the point at which the condenser and magnet are connected, proportional to $I_0\ (R_0 - R_1)$, and the condenser will discharge through the magnet. By using a proper value of capacity the magnet may be made to operate at any required value of this back e. m. f. provided that R_1 be not greater than a certain value which depends on the line constants of the circuit and the periodicity of the condenser and magnet. Should R_1 be greater than this value the trip will not operate because it requires an appreciable time for the energy set free from the condenser to be transformed into mechanical energy in the magnet, and when R_1 is large the back e.m.f. lasts for a very short period. The tripping action is thus not only dependent upon the rate of change of the current but also on the

final value of the resistance. It may therefore be depended on to open the circuit only when the final value of the current would be such as to endanger the circuit.

For slowly varying currents, such as those due to the ordinary overloads, the regular overload tripping arrangement must be included in the breaker, as the condenser trip fails to operate under these conditions.

In case the current increases at such a rate that the ultimate value when the circuit breaker opens will be such as to endanger the circuit, additional inductance may be introduced in the circuit between the source of e.m.f. and the point at which the tripping gear is connected.

A series of tests was made to determine how severe a short circuit a synchronous converter would stand without flashing when protected by this quick-acting breaker and suitable

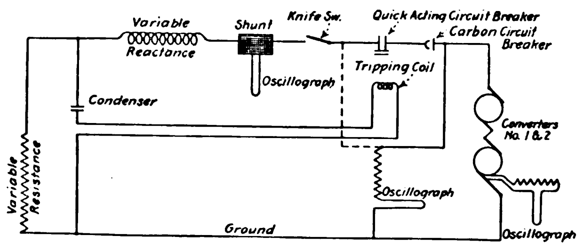


FIG. 11—SYNCHRONOUS CONVERTER WITH QUICK-ACTING BREAKER AND REACTANCE

operating reactance. The converter shown in Fig. 10 was used. This is a 1500-volt, 60-cycle set consisting of two 750-volt converters mounted on a common bed plate and connected electrically in series. The armatures are mechanically separate, though a single bearing housing is used between them. The set is rated at 600 kw., 1500 volts, or 500 kw., 1250 volts, that is, it has a full-load current of 400 amperes. It is three-phase, with a speed of 1200 rev. per min. The oscillograms are marked 400 kw. though the machine will meet the higher ratings without exceeding standard temperature guarantees. The connections for test were made as per Fig. 11.

The oscillograms are shown in Figs. 12 to 22, Fig. 22 simply giving the time for Figs. 12 to 21. It shows a 25-cycle wave taken with the film run at the same speed, and is of no other value. The d-c. circuit of the converter was closed by means of a knife switch as shown in Fig. 11, the load consisting of resistance

which could be varied in amount. The reactor, of air-core type, was so constructed that its reactance could be varied by placing the sections in series or parallel.

In the first tests, as shown by Figs. 12 to 15, the quick-acting circuit breaker was omitted and the circuit was opened non-automatically by means of the carbon circuit breaker after a period long enough to determine whether the load itself would immediately result in flashing. For Figs. 12 to 14 one element of the oscillograph was connected as indicated by dotted lines, to show the voltage across the resistor and choke coil. It will be observed from Fig. 12 that approximately 2100 amperes or 525 per cent normal load current was thrown on and tripped off this converter without flash-over. Figs. 13 and 14 show duplicate tests under heavier short-circuit conditions. The direct current rose to a steady value of 2600 amperes and the converter flashed when the circuit was tripped. Fig. 15 shows test under the same conditions except that the voltage element of the oscillograph was changed to the full line position in Fig. 11 so as to give the machine voltage. In these tests the final direct current was, of course, limited only by the total resistance in the d-c. circuit, although the effect of the reactor in retarding the rise and fall of the current is very noticeable from the films.

For the tests shown by Figs. 16 to 21, the quick-acting breaker was in circuit. The object of the reactor in connection with this breaker was to so affect the rate of increase of current that the breaker would be able to trip out before the current reached such a value as to cause flashing. Fig. 16 shows a test under the same short-circuit conditions as Fig. 15. Figs. 17 and 18 are with reduced resistance in the short-circuit path. As shown by Fig. 19, the resistance was then reduced to approximately 0.1 ohm. The quick-acting circuit breaker started to open the circuit and then arced across the terminals and short-circuited, so that the current—3500 amperes—was practically the same as though the quick-acting breaker had not opened at all. The quick-acting breaker was simply an experimental breaker and did not have the proper insulating clearances which would be given a commercial breaker to meet such conditions. The converter of course flashed over, as would be expected, when the circuit was finally tripped by hand. The next test, as shown by Fig. 20, was made with no resistance except that of the cables and the reactance coil, which later amounted to 0.23 ohm, in the external circuit. The impedance was increased to 13 ohms. The

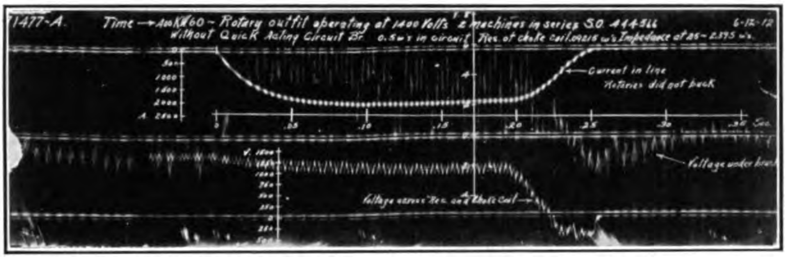


FIG. 12 [YARDLEY]

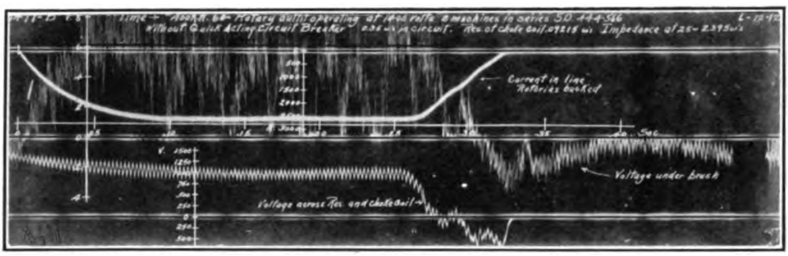


FIG. 13 [YARDLEY]

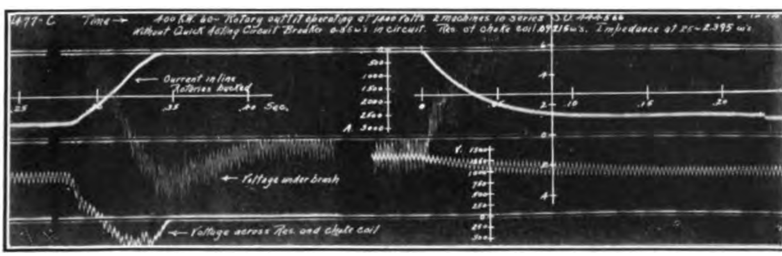


FIG. 14 [YARDLEY]

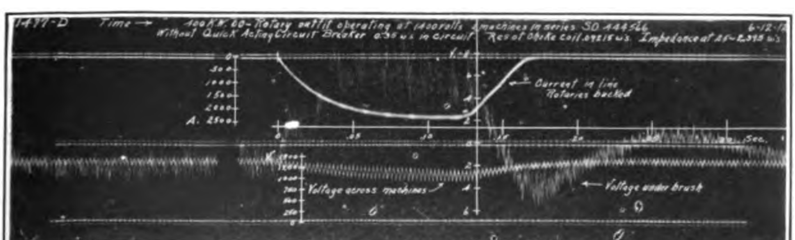


FIG. 15 [YARDLEY]

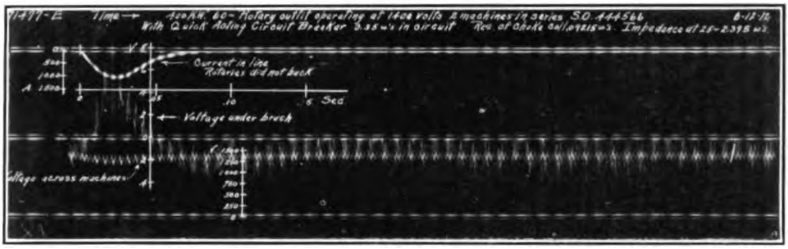


FIG. 16 [YARDLEY]

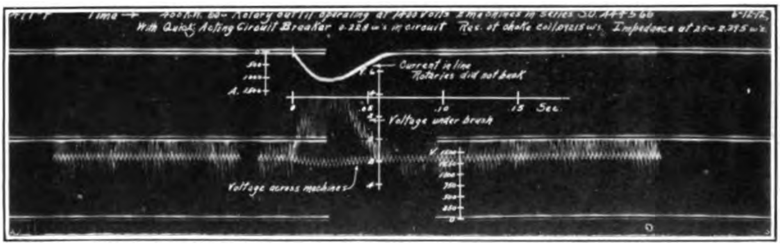


FIG. 17 [YARDLEY]

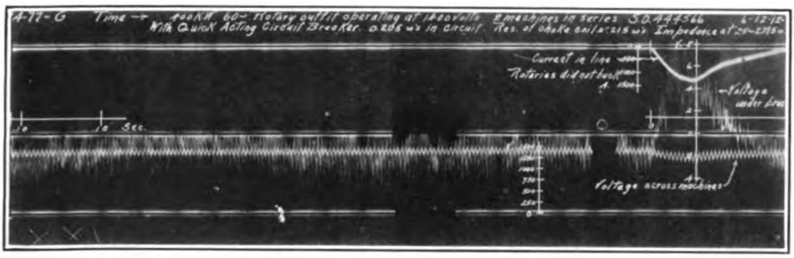


FIG. 18 [YARDLEY]

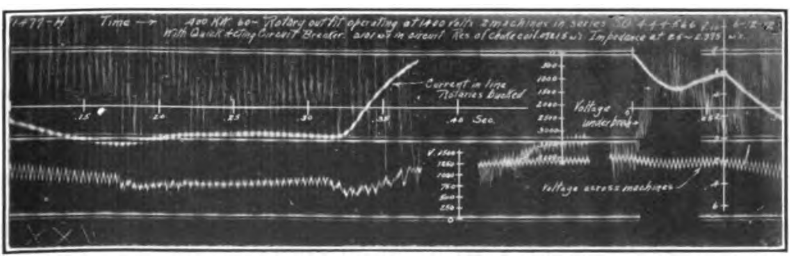


FIG. 19 [YARDLEY]

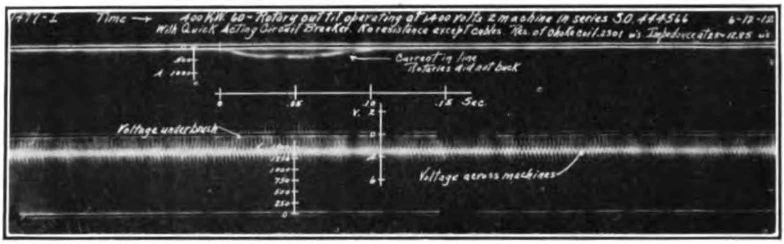


FIG. 20 [YARDLEY]

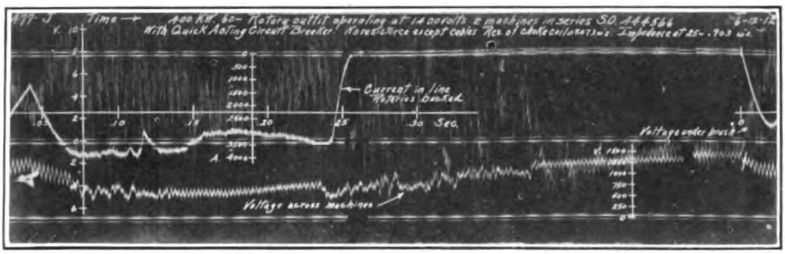


FIG. 21 [YARDLEY]

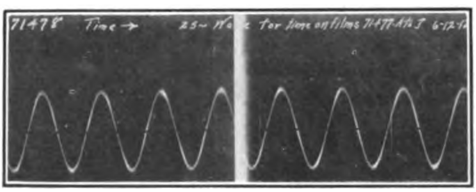


FIG. 22 [YARDLEY]

last test, as shown by Fig. 21, was made with the choke coil resistance of 0.05473 ohm and the cable resistance only in the external circuit and the impedance reduced to 0.903 ohm. This test was made for the purpose of showing how quickly the current would rise under such a short-circuit condition. The breaker opened as in Fig. 19 but arced across terminals and short-circuited, causing a final flow of current of 3900 amperes. It is interesting to note that the converter carried this 975 per cent current load at approximately 700 volts without flash-over, although it of course at once flashed over when the load was tripped off.

These tests are described to establish the fact that, if a properly designed quick-acting circuit breaker be used, and the proper amount of reactance be placed in the d-c. circuit, it is impossible to flash a converter over, as the circuit breaker will trip out the circuit before the current approaches the tripping out flash-over value. As shown by Figs. 12 and 13, this flash-over value for this particular converter is somewhere between 2100 and 2600 amperes. It is interesting to mention that as far as this particular converter is concerned there is scarcely need of such protection under the particular test conditions. The tests were made one right after the other and whenever the converter flashed over the commutator and brushes were so slightly burned that it was unnecessary to do any work on them between tests.

To be presented at the 301st Meeting of the American Institute of Electrical Engineers, New York, November 13, 1914.

(Subject to final revision for the Transactions.)

GRAPHIC METHOD FOR SPEED-TIME AND DISTANCE TIME CURVES*

BY E. C. WOODRUFF

Abstract of Paper

The paper presents a very simple method for obtaining speed-time and distance-time curves, which avoids the usual step-by-step process with its tedious calculations. The method consists of plotting certain so-called " service characteristics " upon the diagram of motor characteristics with the speed-current and traction-current curves. The time and distance increments corresponding to assumed speed increments are found by simple divider operations.

THE FOLLOWING method for obtaining speed-time and distance-time curves is a modification of that brought out by Mailloux in 1902. It is believed to possess certain merits of simplicity, speed, and directness that may make it of interest. It has proved of especial value in teaching the plotting of the above curves to engineering students. Students that have struggled with the usual step-by-step process, involving rather long and tedious calculations, or with graphic methods that require the use of many sets of curves on several sheets, seem to acquire a newinterest in the subject when this method is proposed.

Briefly, the method consists in drawing on the sheet of motor characteristics besides the speed-current and traction-current curves, certain so-called " service characteristics " as shown in Fig. 1 and explained below. From these curves, time and distance increments corresponding to assumed speed increments are found by a few simple divider operations. To avoid confusion, on one of the sheets is placed the motor and service curves for a limited number of load conditions, perhaps for a motor car with and without a trailer, new sheets being readily made for wider variations in train make-up or in motor equipment.

The make-up of a sheet of curves is as follows: Motor speed-current and traction-current curves are plotted to as large a scale as possible from the records of tests. To the same scale

*Manuscript of this paper was received March 26, 1914.

is plotted the train resistance-speed curve, f, from Armstrong's formula, $f = W' \left\{ \frac{50}{\sqrt{W}} + 0.03\,V + 0.002\,V^2 a\,(1 + 0.1\,[N-1]) \right\}$ wherein W is the weight of the whole train in tons, while W' is the load in tons per motor. Horizontal lines are drawn, such as g, whose constant ordinates are the pounds traction required for various grades and curves for W' tons per motor. Using the upper right hand corner as a second origin, net traction is plotted

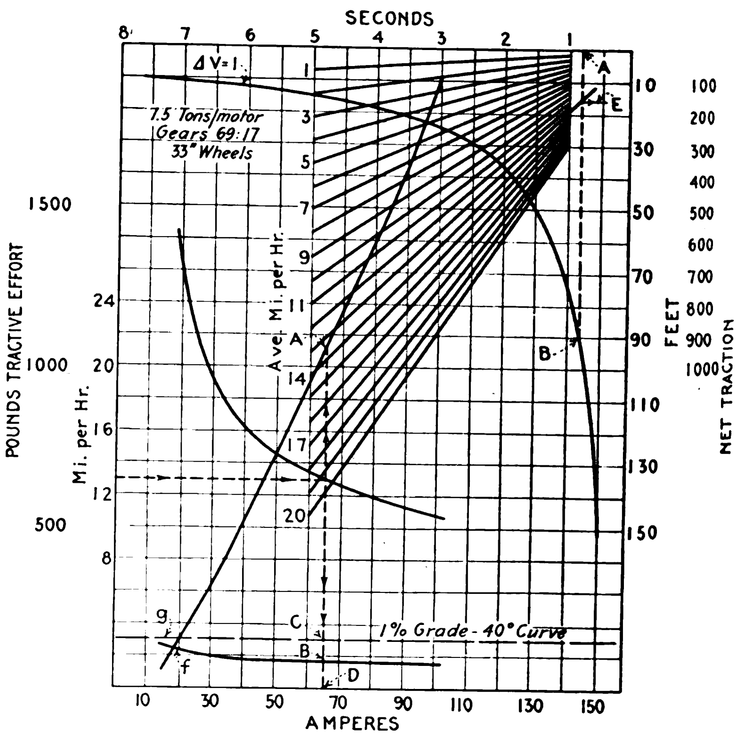


FIG. 1

downward against time increments plotted to the left, using the same scale as for the traction-current curve. This gives one or more hyperbolas whose equations are $T_n \times \Delta t = \Delta v \times 100\, W'$, wherein T_n is net traction, Δt is a time increment, W' is the tons per motor, 100 is a constant including 91.1 plus an allowance for the energy of the rotating parts, and ΔV is a speed increment, constant for each hyperbola. From the same corner are drawn a series of radii intercepting equal distances on the

vertical lines. These radii, labelled 1, 2, 3, etc, are lines of average velocity, a scale of corresponding distance increments running downward from the corner at the right. This distance scale is so selected that projection vertically from some time division, such as 5, to a radius, such as 15, and then horizontally to the distance scale will indicate the distance travelled, in this case 110 feet, during the selected time interval at the indicated average velocity.

To use the curves on the motor sheet, Fig. 1, to obtain the car characteristics curves, Fig. 2, proceed as follows: The points on

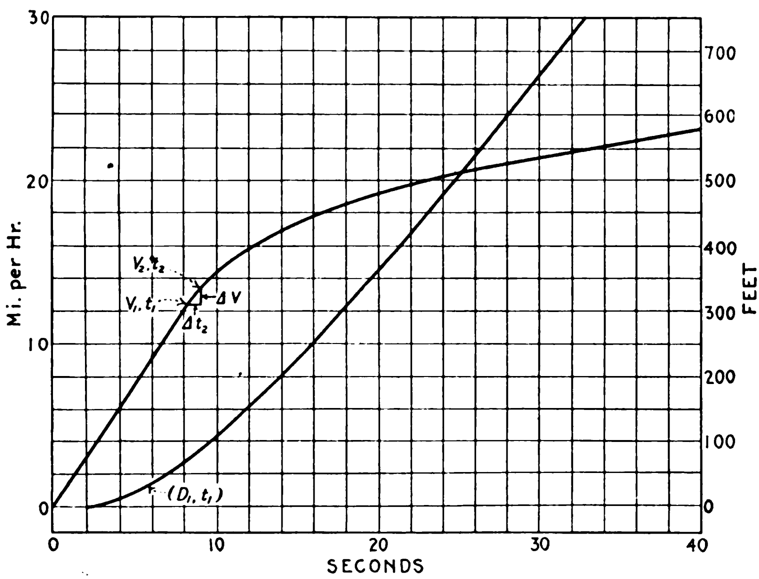


FIG. 2

the curves of Fig. 2 that mark the end of running on control (V_1, T_1), (D_1, T_1), are found in the usual way from initial assumptions. To find the point, (V_2, T_2) on the speed-time curve, assume $\triangle V_2 = (V_2 - V_1)$. On the mi-per-hr. scale at the left of the motor sheet, find the division representing the average speed, $(V_2 + V_1) \div 2$. Project horizontally to the speed-current curve and from there vertically to the traction-current curve. Set one divider point on the traction-current curve and the other on the train resistance curve, f, in the same vertical line. Increase or decrease the divider setting by the ordinates of the proper grade and curve lines if necessary. Slide one di-

vider point along the axis of time increments at the upper edge of sheet, keeping the points in the same vertical line, until the other point intersects the hyperbola whose constant was the assumed speed increment. Then the first divider point indicates the time increment, ΔT_2, and the second point on the speed-curve is determined. Drop vertically from the division ΔT_2 on the time increment scale to the radius labelled with the average speed, $(V_2 + V_1) \div 2$ and read the corresponding distance increment on the scale to the right. Proceed thus for successive points on the car curves, changing the assumed speed increment as desired to gain accuracy. For example if the coordinates of the point (V_1, T_1) that terminates linear acceleration are 12.5 mi. per hr. and 8 sec., and 1 mi. per hr. is the first assumed speed increment, 13 mi. per hr. is the average speed and the dotted lines and arrows in Fig. 1 show the proper projections. A-B is the divider setting for net traction for a level tangent track at 13 mi. per hr. This would become A-B less C-D for a 1 per cent grade. A-B transferred to the hyperbola, $\Delta V = 1$, coincides with A'-B'. Then at A' is read 0.8 sec., and the dotted projection from A' shows at E that the distance travelled during 0.8 sec. was 15 feet.

On the motor sheet may be drawn as many train resistance, grade, and curve lines, and as many hyperbolas for different tons load per motor as desired. It seems best, however, to limit the curves on one motor sheet to those for only two different motor loads, such as motor car with and without trailer, one- and two-car trains, etc., and to draw new sheets for widely separate classes of service. The labor involved in getting ready for the graphical work is so slight that the method saves time and trouble even when one has to plot but a single speed-time curve for a particular motor load.

To be presented at the 301st Meeting of the American Institute of Electrical Engineers, New York, November 13, 1914.

(*Subject to final revision for the Transactions.*)

THE CORONA PRODUCED BY CONTINUOUS POTENTIALS*

BY STANLEY P. FARWELL

Abstract of Paper

This paper deals with an experimental investigation of the corona around small wires as produced by continuous potentials up to 15,000 volts. The continuous potentials were obtained from a series of 500-volt generators.

The wire and coaxial cylinder method was employed for a number of experiments. Critical voltages and characteristic potential difference and current curves were obtained for different sized wires. The effect of lowering the pressure in the cylinder upon appearance of corona, critical voltage, and current, was studied. It was found that the appearance of the corona depended upon the polarity of the wire; positive polarity gave continuous glow, while discontinuous beaded appearance characterized the negative corona, the number of beads being a function of the pressure and the potential difference for a given size wire. A short arc in series affected the nature of the discharge by superimposing a high-frequency current upon the direct current. Characteristic curves were taken to show the effect of varying pressure, moisture and temperature. An increase of pressure inside the closed cylinder was produced by the application of a potential difference greater than the critical value; this increase is due to ionization.

Corona in the case of parallel wires was studied by taking characteristic curves and exploring the field. Field exploration showed anode fall of potential greater than cathode. Corona accompanied by mechanical effects on wires; deflection on both wires and circular vibration of positive wire.

The Direct Current Corona

In alternating-current transmission lines at very high voltages a loss occurs by dissipation of power into the air. This is accompanied by luminosity of the air surrounding the conductors, and to this glow the name "corona" has been given. Loss begins at some critical voltage, depending on the size and spacing of the conductors, etc., and increases very rapidly above this voltage. This corona effect is of considerable importance, as it involves a power loss of some magnitude on long lines and it has been studied by Steinmetz, Scott, Ryan, Mershon, Jona, Peek, Whitehead and others.

The corresponding direct-current case, although not of such immediate importance, is yet of considerable interest in view

*Manuscript of this paper was received October 5, 1914.

of the high-tension direct-current developments on the continent of Europe. The only work of much importance along this line has been done by Watson[1] and Schaffers.[2] Watson has carried out a number of tests of wires strung axially along a cylindrical tube and also on two parallel wires out-of-doors. The wires used were of various diameters between 0.70 mm. and 12.76 mm. The source of power was an influence machine of special design and large output and would give any potential required up to 70,000 volts.

The electric stress at the surface of a wire subjected to electric potential is as follows:

Wire in cylinder:

$$R_{max.} = \frac{V}{a \log_e \frac{b}{a}}$$

Two parallel wires:

$$R_{max.} = \frac{V}{2_a \log_e \frac{d}{a}}\left(1 + \frac{a}{d}\right)$$

where V = potential difference between wires, or between wire and cylinder,
a = radius of wire,
d = distance apart of wires,
b = radius of cylinder.

Of these formulas, the first is exact, while the second is only approximate, but is very nearly correct for all ordinary cases where a is small compared to d, and the wires are well above the earth.

The value R_{max} in the above formulas is called by some writers the "critical surface intensity" and is extensively used in expressing the results of tests. It has been well established by Watson, Whitehead and others that this critical surface intensity increases very greatly as the radius of the wire decreases. A comparison made by Whitehead of his results for this intensity in the case of alternating potentials with the similar values deduced by Watson for continuous potentials shows that for a given size of wire it requires the same voltage to produce corona in both cases, if the maximum value of the alternating potential be used.

1. Watson, *Electrician-London*, Vol. 63, 1909, p. 828; Vol. 64, 1909-10, pp. 707 and 776.
2. Schaffers, *Comptes Rendus*, July 1913, p. 203.

For the case of a wire in a cylinder Watson found some differences between the case where the wire was positive to the cylinder and when it was negative to it, these differences occurring both in the appearance of the corona and in the measurements relating to it.

The article by Schaffers referred to above, gives the results of a study of the ionization in cylindrical fields, using wires of various diameters ranging from 0.0006 cm. to 0.70 cm. in tubes ranging from 0.70 cm. to 11.7 cm. in diameter. He says nothing of the source of potential used or of the appearance of the coronas. He finds that for the larger size wires the positive corona appears at a lower voltage than the negative and that for the smaller sizes, the reverse is true, the radius 0.01 cm. separating these two regions. Another conclusion reached by this investigator is that the nature of the material of the wire is without effect upon the coronal voltage, at least if the wires are not very fine.

When this investigation was undertaken, there was no physical theory advanced which explained the phenomena observed. During the progress of this work, however, two theories were published, one by Bergen Davis (PROC. A.I.E.E., April, 1914, p. 529) the other by J. E. Townsend (*Phil. Mag.*, May, 1914,) which try to explain the phenomena by ionization through collision. Both theories neglect the influence of light and a number of phenomena that have been discovered in the present investigation.

In view of the scarcity of certain data as to the corona at continuous potentials, the object of the work described in this paper has been to extend our experimental knowledge in this direction.

DETAILS OF EXPERIMENTAL APPARATUS

The source of the continuous potentials employed was a battery of small continuous-current generators connected in series. There were thirty of these, each rated as follows: Amperes, 0.5; watts, 250; speed 1700; volts, 500; shunt-wound. The potential available, then, was 15,000 volts when the machines were run at normal voltage.

These generators were arranged in two sets, one of twenty machines and the other of ten. The generators were self-excited and could be put into service by closing a small knife-switch in each field circuit. Voltage control was obtained in this manner and by controlling the speed of the set by field

control of the driving motor. A fine adjustment of voltage was obtained by means of a rheostat in the field circuit of one of the generators. The series connection between the machines was permanent.

The diagram of connections in Fig. 1 is self-explanatory. The apparatus labeled "Short Arc" consists of an air-gap between the head of a tack and a copper wire. This spark-

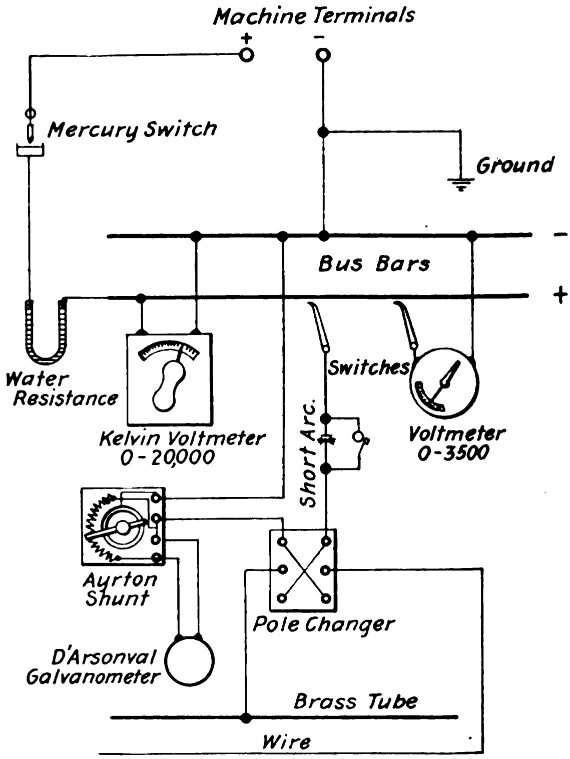


FIG. 1—DIAGRAM OF CONNECTIONS

gap could be cut out of the circuit by closing a shunt around it. Special care was taken in setting up the apparatus to thoroughly insulate it from the ground, except that the negative terminal of the generating apparatus was grounded, in order to minimize the danger from shock.

The voltage between the busbars and hence, with sufficient accuracy, the difference of potential impressed upon the corona

apparatus, was measured by means of electrostatic voltmeters. For the lower ranges an instrument was employed having a range of 3500 volts and accurate to within one per cent. This conclusion was reached by comparing its indications with those obtained by adding the voltages of the machines used as given by a 750-volt direct-current portable voltmeter which had been carefully calibrated.

For the measurements of the higher differences of potential a vertical type Kelvin electrostatic voltmeter was used. This instrument had three ranges of 5000, 10,000, and 20,000 volts which could be secured by hanging the proper weights from a lug at the bottom of the needle. Only the 10,000 and 20,000 ranges were used. The lower part of the 10,000 range was calibrated by the same method as for the lower range voltmeter as well as by measuring the voltages indicated by the portable voltmeter when a high resistance was inserted in series with it. This high resistance was made of a *U*-tube containing alcohol into which two platinum wires dipped. This resistance was kept from heating by immersing it in a mixture of ice and water. Under these conditions the resistance was very constant for the small currents used.

The higher ranges of this voltmeter were calibrated by reference to an attracted disk electrometer. This instrument had a disk 5.5 cm. in diameter. The aperture of the guard-ring was 5.9 cm. in diameter and the outside diameter of the guard ring was 16.0 cm. A separation of 1.5 cm. was used between the disk and the lower plate.

Due to the non-uniformity of the field at the edge of the disk, an edge correction must be applied to the indications of the electrometer. This edge correction is treated by Maxwell in Vol. 1 of his "Electricity and Magnetism" and the conclusions reached are briefly as follows:

Let

R = radius of disk
R' = radius of aperture
D = distance between plates
A = effective area of disk
$\alpha = 0.220635\ (R' - R)$
W = wt. in grams to balance.

Then

$$V = D\sqrt{\frac{8\,\pi\,g\,W}{A}}$$

where

$$A = \frac{1}{2}\,\pi\left[R^2 + R'^2 - (R'^2 - R^2)\frac{\alpha}{D + \alpha}\right]$$

Using the numerical constants of the instrument as given above, there results:

$$\alpha = 0.044$$
$$A = 25.474 \text{ sq. cm.}$$

We may write $V = k\sqrt{W}$, where k is the constant

$$D\sqrt{\frac{8\,\pi\,g}{A}}$$

Then $k = 13{,}992.3$. By a similar series of operations we find that for plates 1 cm. apart, $k = 9357.6$.

By use of the value $k = 14{,}000$, which is nearly enough correct, the values of W to balance for different voltages were calculated and a test run to determine how closely these values checked with the actual weights required for a balance when the voltages indicated by the electrostatic voltmeter were impressed. A consideration of these figures with due regard to the accuracy of the determinations led to the final calibration.

D'Arsonval galvanometers were used to measure the discharge currents obtained with the various pieces of corona apparatus. Most of the characteristic curves were taken with a very sensitive galvanometer which had a small coil, a resistance with connecting wires of 326.0 ohms, and was practically dead-beat. For the later moisture and pressure determinations which extended over some days, a less sensitive instrument was used. This had a heavier coil, a resistance with connecting wires of 849.5 ohms and a period of six seconds. Its figure of merit was about five times that of the first instrument.

The figure of merit of these galvanometers was determined from time to time, using accurate resistances of high value and as a source of e.m.f. either a dry cell or a standard cell. In the case of the dry cell, its e.m.f. was determined from the indications of an accurate laboratory standard voltmeter. An Ayrton universal shunt was used in connection with the galvanometer. This shunt box had five coils connected between contact points.

Preliminary Experiments

When this work was first undertaken, it was not apparent from the limited literature of the subject what one might expect in the way of coronal phenomena which might be produced by potentials up to the total voltage of the generating sets, namely 15,000 volts. No glow could be obtained between flat plates; only an arc. Then an investigation was begun to find out what kind of terminals would have corona produced between them by the comparatively low voltage available.

A brass rod, 0.637 mm. in diameter, was located axially along a tube 4.45 cm. in diameter and the full voltage of the sets was impressed. No effect was visible. Then provision was made for exhausting the tube, and at about one-quarter atmosphere a discharge took place. This took the form of brilliant radial purple arcs terminating in bright blue "stars" on the walls of the tube. These arcs were in constant motion around the wire and along the tube and reminded one of a pin-wheel. A fairly large size wire was substituted for the rod and still no corona could be obtained at atmospheric pressure.

Recourse was next had to large influence machines. It was known that the silent discharge between points was of the same nature as the corona between wires and it was reasoned that if the e.m.f. of an influence machine were impressed between small parallel wires, a discharge would take place between them. Two bare No. 40 wires were stretched parallel to one another and a few centimeters apart, and a silent discharge was found to take place between them. The appearance of the discharge was at once seen to depend upon the polarity. The discharge was discontinuous, small brushes on the negative wire corresponding to sections of uniform glow on the positive wire. The brushes were in a more or less constant movement back and forth along a short path, but they appeared to be more or less evenly spaced along the wires. It was also noticed that the wires vibrated and that the negative wire bowed in toward the positive, which bowed away from the negative. It was as though a wind were blowing across the wires.

Another experiment was tried with a No. 40 wire above a sheet of tinfoil. With this arrangement and wire positive, a continuous glow appeared along the wire, while when the wire was negative the discontinuous brush discharge appeared again. Vibrations were also noticed with this apparatus.

A mandolin steel "*E*" string, 0.24 mm. in diameter was

strung along the axis of a brass tube of about 3 cm. diameter and the wire and tube were connected to opposite polarities of the influence machine. If the wire was positive, a continuous bluish glow of markedly uniform appearance appeared along the wire. When the wire was negative, the discharge was in constant movement and seemed to consist of countless purple streamers or brushes. There seemed to be no appearance of regularity of spacing of isolated brushes.

When these tests were run it was noticed that the main discharge knobs on the machine could be moved together until they almost touched before a spark would pass. This indicated that the difference of potential between the parallel wires, for example, could not be very high, not over 10,000 volts perhaps. This fact suggested that similar discharges with small wires should be produced by the continuous potentials from the generating sets. So the experiments were carried out again and it was found that the same effects were produced by the generators.

The crude tube apparatus was fastened to a board by means of nails driven into the wood and bearing against the wall of the tube. Connection was made to the tube by wrapping a wire around one of these wires. This wire became loose and separated 0.01 inch or so from the tube. The consequence was that a short arc was established between the wire and the tube. The presence of the arc caused a marked difference in the character of the positive discharge. With a potential difference of about 8000 volts and the wire positive to the tube, a very active discharge took place between the wire and tube. The whole tube appeared filled with a bluish glow particularly brilliant around the wire, where an uneven effect was apparent, resembling a brush discharge. The discharge was unstable and variations in the arc produced marked variations on the discharge. After the bluish glow had continued for some minutes, the nature of the discharge became suddenly different. Purple arcs appeared, of much the same nature as those mentioned above in connection with the discharge from a rod at low pressure. After a while the discharge would resume its former character and then the process would repeat. The arc between the nail and tube appeared bluer while the whirl-i-gig discharge was going on. A small wire was slipped in to bridge the gap between nail and tube and then the discharge became merely a faint blue glow of a uniform nature, apparent only in

the immediate vicinity of the wire. With the gap closed the wire negative, an entirely different discharge took place. Small purple brush-like discharges were clustered irregularly along and around the wire and these held their positions fairly constant. When the arc was again introduced, the discharge appeared somewhat dimmer, although keeping its nature about the same, as far as could be seen by looking from the end of the tube.

Characteristic Curves at Atmospheric Pressure

In order to study the influence of diameter of wire upon critical voltage and discharge current, a number of different sizes of bare wire ranging from No. 40 to No. 10, copper, were obtained from the manufacturers and an apparatus was constructed in which the tests could be carried out. This apparatus consists essentially of a brass tube 4.45 cm. in internal diameter, well insulated from its support and provided with means for accurately and tightly stretching a wire along its axis. The tube was provided with a small branch tube through which the air could be exhausted. The centering of the wire was accomplished by passing it over hard-rubber bridges in which there were notches axially located with respect to the tube and stretching it tightly by means of a mandolin tension-head. In order to limit definitely the length of the wire from which a discharge could take place, glass plates were sealed to the ends of the tube and the wire passed through holes in them about 3 mm. in diameter. For most of the characteristic voltage-current curves, the exhaust tube and the holes in the plates were left open and the air in the tube had the same constitution as that in the room, at least at the beginning of the test.

In order to make sure that no current would flow through the apparatus except that through the air, a small wire was arranged so that the tube was in the same condition as for a test except that none of the wire extended inside of the cylinder. Then differences of potential were applied up to 10,000 volts and the currents measured. It was found that even at the highest voltage the current was insignificant.

For the first wires tested, a start was made at a low voltage and the currents taken by small increments on the way up. It was soon found that the current flowing was negligible until the voltage approached that necessary for a visible glow and therefore later tests were started at a voltage somewhere near

the critical voltage. For each voltage the deflection of the galvanometer was read for both polarities of the wire.

When the wire was positive and the voltage neared that necessary to cause a visible glow, a very marked jump of the deflection would occur and a further increase of the voltage caused the current to increase very rapidly. The voltage at which this sudden increase of the deflection took place was called the "critical voltage." "Visible glow" was taken to mean the first appearance of light in the case of the wire positive. This glow appeared suddenly for all but the smallest wires, in which case the dimness of the glow made it hard to tell just where the limit of visibility was.

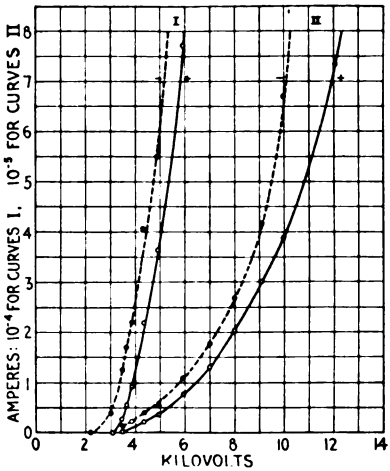


FIG. 2—CHARACTERISTIC: SILVER WIRE 0.037 MM. DIAMETER

Tube 4.45 cm. diameter, 25 cm. long; temperature 26.7 deg. cent.; relative humidity 45.3 per cent; barometric pressure 736.48 mm.

As has been noted, the presence of dirt or dust particles on the wire, when negative, has a marked effect upon the discharge. Often a spot or two on the wire would glow long before the wire as a whole was luminous. Due to this fact there is no definite critical voltage as in the case of the positive polarity, for the initial jump of the deflection is much a matter of chance. But as the voltage is increased, there occurs a critical voltage at which a flickering glow can be seen along the wire preliminary to the spreading of the discharge from a few spots over the whole wire. This phenomenon occurs at a definite voltage for a given size wire and it is this voltage which is given in the tables under "visible glow" for the negative polarity.

Readings of wet and dry bulb thermometers and an aneroid barometer were taken for each test and the per cent relative humidity was calculated. The barometer was checked from time to time by reference to a very accurate mercurial barometer.

The silver wire used in these tests was really silver wire with a platinum core, known as "Wollaston" wire. This wire was used both in its original state, diameter 0.0517 mm. and with some of the silver dissolved off, giving wires of average diameter 0.027 and 0.037 mm.

The tungsten wire was of the sort used in 25 watt lamps.

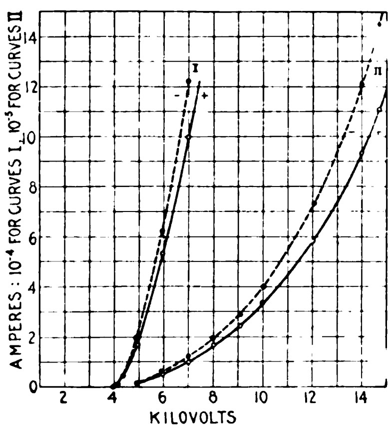


FIG. 3—CHARACTERISTIC: NO. 40 B. &. S. COPPER WIRE, 0.077 MM. DIAMETER

Tube 4.45 cm. diameter, 25 cm. long; temperature 25 deg. cent.; relative humidity 41.6 per cent; barometric pressure 745.3 mm.

The diameters of the very small wires were obtained by the use of a microscope fitted with a stage ruled with parallel lines.

VARIATION OF CRITICAL VOLTAGE AND GLOW VOLTAGE

Tables 1 and 2 give data on critical voltages and the voltages required to produce continuous visible glow for wires of diameters ranging from 0.027 mm. up to 1.28 mm. and are plotted in Fig. 2. Similar tables for Figs. 3, 4 and 5 are cmitted. A study of this data showed the following facts:

a. For the smaller sizes, the critical voltage is considerably lower than the glow voltage, showing quite a current exists before a luminous discharge occurs. This applies for wire positive.

TABLE 1.

Silver Wire—Diameter 0.027 mm.
Temperature 26.6 deg. cent.
Relative Humidity 54.4 per cent.
Barometric Pressure 741.55

	+	—
Critical Voltage	2100	1880
Visible Glow	2720	2520

Potential Difference	Galv. defl. in mm. +	Galv. defl. in mm. —	Shunt Factor +	Shunt Factor —	Current in 10-4 amp. +	Current in 10-4 amp. —
1750	1.1	1.2	1.0	1.0	0.000032	0.000035
2100	25.0	60.0	1.0	1.0	0.00072	0.00173
2500	66.7	50.7	1.0	11.09	0.00192	0.0162
2800	137.0	101.0	1.0	11.09	0.00394	0.0322
3000	18.2	147.0	11.09	11.09	0.0058	0.0469
3200	33.0	21.1	11.09	110.9	0.0105	0.0674
3500	101.0	36.7	11.09	110.9	0.0322	0.117
3860	30.9	69.0	110.9	110.9	0.0986	0.220
4350	66.2	122.8	110.9	110.9	0.212	0.392
4920	114.8	18.4	110.9	1109	0.335	0.588
5950	23.9	35.2	1109	1109	0.763	1.12
7000	39.4	56.7	1109	1109	1.26	1.81
8000	60.7	87.5	1109	1109	1.94	2.80
9100	82.0	113.0	1109	1109	2.62	3.61
			wire broke			

Wire rough: 0.027 is average of many readings.
Figure of merit of galvanometer 2.88 × 10^{-9} amp. per mm.

TABLE 2.

Silver Wire—Diameter 0.037 mm.
Temperature 26.7 deg. cent.
Relative Humidity 45.3 per cent.
Barometric Pressure 736.48 mm.

	+	—
Critical Voltage	3100	2200
Visible Glow	3380	3230

Potential Difference	Galv. defl. in mm. +	Galv. defl. in mm. —	Shunt Factor. +	Shunt Factor. —	Current in 10^{-4} amp. +	Current in 10^{-4} amp. —
2150	1.5	2.1	1.0	1.00	0.00004	0.00006
3000	4.0	117.0	1.0	11.09	0.00011	0.0374
3500	85.7	39.3	11.09	110.9	0.0274	0.126
3650	117.7	53.3	11.09	110.9	0.0565	0.170
3860	29.0	68.8	110.9	110.9	0.0926	0.220
4350	68.8	127.7	110.9	110.9	0.220	0.407
4920	114.3	172.7	110.9	110.9	0.365	0.551
5950	242.0	34.4	110.9	1109	0.773	1.10
7000	41.0	56.0	1109	1109	1.31	1.79
8000	64.0	84.0	1109	1109	2.04	2.68
9100	94.7	131.0	1109	1109	3.02	4.18
10000	121.7	21.0	1109	11090	3.88	6.7
12075	23.0	58.7	11090	11090	7.35	18.8
14000	... wire broke—		arc.	...	....	....

Figure of merit of galvanometer 2.88 × 10^{-9} amp. per mm. defl.

b. The smallest size for which there is no current for wire positive before glow appears is No. 36, diameter 0.136 mm.

c. For sizes larger than No. 36, current and glow appear simultaneously, for wire positive.

d. For wires from about No. 26 up for the negative polarity, the current and the visible glow appear simultaneously, as a general rule.

Fig. 6 gives curves showing the variation of the glow voltages with the radius of the wire. From these curves the following conclusions can be drawn:

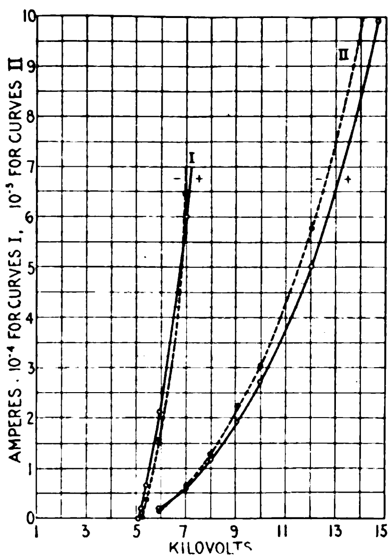


FIG. 4—CHARACTERISTIC: NO. 36 B. & S. COPPER WIRE, 0.135 MM. DIAMETER

Tube 4.45 cm. diameter, 25 cm. long; temperature 25 deg. cent.; relative humidity 45 per cent; barometric pressure 733.85 mm.

e. For the smaller sizes, the negative glow appears before the positive.

f. For the larger sizes the positive glow appears before the negative.

g. The diameter 0.075 mm. is the boundary between these two regions.

Schaffers has noted this crossing of the curves for the starting points of the positive and negative corona and he gives 0.01 cm. radius as the boundary value between the two regions. He does not specify what he considered as the starting point

of the negative corona and therefore it is not practicable to compare his value with that given above.

VARIATION IN THE NATURE OF CORONA

During the tests for the characteristic curves a close watch was kept over the appearance of the corona, and there are given below some of the characteristic changes and phenomena which were noted.

For the entire range of diameters there was very little change in the appearance of the positive corona, except for an increase in brightness with the voltage. It always presented a quiet, uniform, continuous, bluish glow. For high voltages the opening and closing of the circuit was attended by a flash of bluish light in the tube and if care was not taken to perform these operations quickly, there was likelihood of an arc starting between the wire and the tube, with the result that the wire, if it was small, was burned in two.

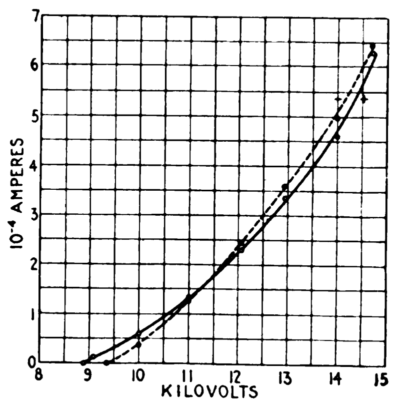


FIG. 5—CHARACTERISTIC: No. 26 B. & S. COPPER WIRE, 0.41 MM. DIAMETER

Tube 4.45 cm. diameter, 25 cm. long; temperature 26 deg. cent.; relative humidity 29.2 per cent; barometric pressure 746.86 mm.

There was considerable change, however, in the appearance of the negative corona with increase of diameter and voltage. The negative corona on small wires starts with a bright spot or two, followed by a mixture of bright spots and brushes as the voltage is increased. With still increasing voltage there is more of a continuous brush-like effect and the discharge becomes quite purple. For the highest voltages the corona is brilliant, purple, continuous, and in constant movement. For

the smallest sizes, the negative corona is likely to take the form of a discharge consisting of isolated, more or less evenly spaced brushes. Marked regularity of spacing has often been observed. The discharge is noiseless for wires up to No. 26 (0.24 mm.) for which diameter a slight hissing appears. As the diameter increases, the hissing grows louder and the diameter of the corona increases.

In the case of the larger size wires, it is the general rule for the continuous negative brush discharge to appear immediately when the critical voltage is reached.

No flash at make or break of the circuit was observed when the wire was negative.

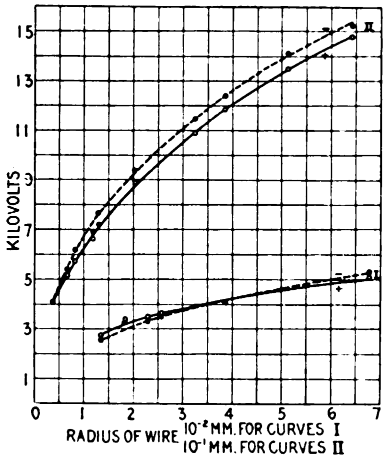


Fig. 6—Difference of Potential to Cause Continuous Glow, as Function of Radius of Wire

Tube 4.45 cm. diameter, 25 cm. long.

Discussion of the Characteristic Curves

A critical comparison of the characteristic curves in Figs. 2 to 5 brings out the following points:

a. For a given voltage, the current increases with decrease of diameter of the wire also with decreasing pressure.

b. For wires smaller in diameter than No. 40 (0.077 mm.), the current for negative polarity of the wire is always greater than for positive polarity.

c. In the case of No. 40 wire the currents for opposite polarities coincide very accurately for a small rise in voltage above the critical value, and then the negative current becomes and remains the larger.

d. For sizes larger than No. 40, the curves for the two polarities cross. For the lower voltages the positive current is the greater and *vice versa* for the higher voltages.

e. The characteristic curves become more nearly parallel to the current axis as the diameters increase.

Table 3 contains the critical and the glow voltage as functions of the radius of the wire, Table 4 the glow voltage and the maximum electric intensity at the surface of the wire as function of the radius. While with increasing radius the glow voltage increases, the electric intensity E at the surface of the wire decreases. Fig. 6A shows this relation graphically. As has been found by previous investigators this electric force E can be represented by the following law $E = a + \frac{b}{\sqrt{R}}$. For the

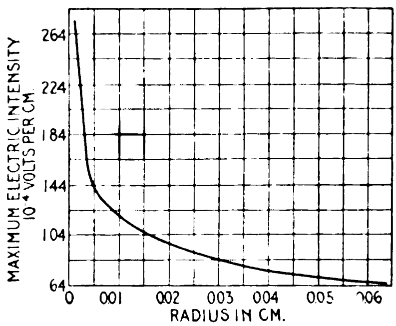


FIG. 6A

smallest wires, there are deviations from this formula, as we should expect, because the critical voltage and the glow voltage differ from each other and as very probably there is a distortion of the field due to ionization before the glow sets in as in the case of two parallel wires. For the positive wire we found $a = 31.6 \times 10^3$; $b = 8.47 \times 10^3$, for the negative wire $a = 35.0 \times 10^3$; $b = 8.06 \times 10^3$.

Influence of Pressure on Coronal Current

The effect of variation of pressure on the voltage to cause continuous glow was studied for a No. 26 wire by varying the pressure in the tube from 768 mm. down to 2 mm. and the results are given in Table 5 and shown by curves in Fig. 7. Below about 20 mm. pressure it was found impossible to get

a negative uniform glow. Instead of this there appeared a series of beads approximately equally spaced along the wire.

It was found that measurements of the coronal current for

TABLE 3.

CRITICAL DIFFERENCE OF POTENTIAL TO CAUSE CONTINUOUS GLOW AS FUNCTION OF RADIUS OF WIRE.

Radius in mm.	Material	Critical Voltage	Positive glow	Critical Voltage	Negative glow.
0.0135	Silver	2100	2720	1880	2520*
0.0185	Silver	3100	3380	2200	3230*
0.0230	Tungsten	3380	3500	2800	3300
0.0258	Silver		3630		3500
0.0386	No. 40 Copper	3980	4060	3860	4060
0.0678	" 36 Copper	5120	5140	4350	5320
0.0825	" 34 Copper		5710		6140
0.120	Steel " E " String	6600	6600	6760	6840
0.130	" 30 Copper	7180	7180		7660
0.205	" 26 Copper	8900	8900	9370	9370
0.325	" 22 Copper	9700	10880	11440	11440
0.385	" 20 Copper	11850	11850	12075	12400
0.512	" 18 Copper	13500	13500	14040	14120
0.642	" 16 Copper	14700	14700	15220	15220

*These values uncertain on account of dimness of glow.

TABLE 4.

R cm.	V +volts.	E +volts per cm.	E +calcul.	V −volts.	E −volts per cm.	E −calcul.
0.00135	2720	2.74×10^5	2.62	2520	2.52×10^5	2.55
0.002185	3380	2.58	2.29	3230	2.45	2.23
0.0023	3500	2.25	2.09	3300	2.08	2.04
0.00258	3630	2.12	1.99	3500	2.02	1.94
0.00386	4060	1.66	1.67	4060	1.66	1.65
0.00678	5140	1.31	1.34	5320	1.36	1.33
0.00825	5710	1.25	1.25	6140	1.21	1.21
0.012	6600	1.07	1.09	6840	1.09	1.09
0.013	7180	1.07	1.06	7660	1.14	1.06
0.0205	8900	0.93	0.91	9370	0.99	0.92
0.0325	10880	0.80	0.79	11440	0.83	0.80
0.0385	11850	0.77	0.75	12400	0.79	0.76
0.0512	13500	0.71	0.69	14120	0.73	0.71
0.0642	14700	0.65	0.65	15220	0.64	0.64

the same wire gave different results on different days and it was considered advisable to find out the influence of pressure for a range around atmospheric pressure in order that the

current readings for the different sizes of wire might be reduced to a 760 mm. basis. Therefore a series of characteristic curves was taken for different pressures with dry air in the tube to do away with any effect which might be due to the moisture in the air. Fig. 8 shows the results obtained. These curves show a marked increase in the current for a relatively small decrease in the pressure. The curves also show an unsymmetrical spacing which suggests the presence of some disturbing factor.

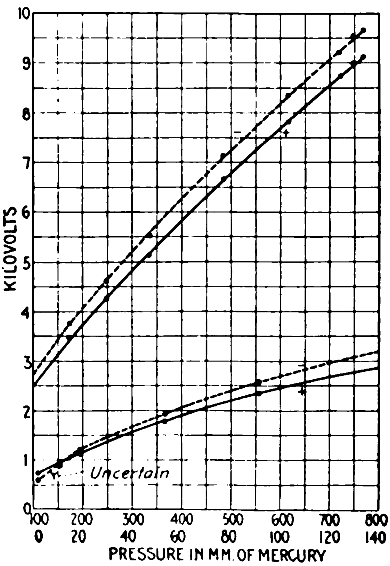


FIG. 7—GLOW VOLTAGE AS FUNCTION OF PRESSURE IN TUBE

No. 26 B. & S. copepr wire, diameter 0.41 mm.; tube 4.45 cm. diameter, 25 cm. long dry air at 25 deg. cent. in tube.

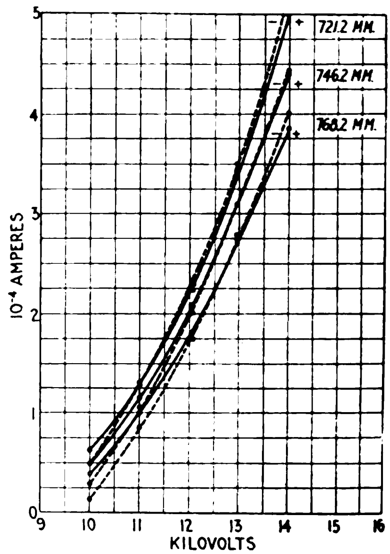


FIG. 8—CHARACTERISTICS FOR VARYING PRESSURE

No. 26 B. & S. copper wire, diameter 0.41 mm.; tube 4.45 cm. diameter, 25 cm. long; dry air at 25 deg. cent. in tube.

In a number of preliminary experiments it was found that it was not possible to repeat observations if the tube was closed and the air not changed. In order to do away with any pisturbing effects due to moisture in the air and possible changes in the constitution of the air in the tube, an arrangement was devised for supplying dry air which could be pumped through the tube out into the atmosphere. The air was dried by passing it through two wash-bottles containing concentrated sulphuric acid and then through a tube containing soda-lime. A No. 40 wire was strung in the tube and as the atmospheric pressure

varied from day to day, series of readings were taken as given in Table 7. The general decrease of current with increase of pressure is apparent. The readings for the extreme pressures

TABLE 5.

VARIATION OF CRITICAL VOLTAGE WITH PRESSURE.

No. 26 B. & S. Copper Wire. Diameter 0.41 mm. Dry Air at 25 deg. cent.

Pressure in mm.	Potential Difference for Continuous Glow	
	+	−
2.0	720	*580
10.9	940	*870
18.9	1110	1200
53.2	1770	1920
91.3	2350	2580
173.5	3450	3750
248.5	4250	4610
334.8	5120	5520
483.6	6660	7120
616.6	7800	8330
720.0	8730	9210
746.0	8980	9530
768.3	9100	9640

No continuous glow obtainable—voltage is that of formation of beads.

TABLE 6.

p in mm.	$V-$ in volts.	$E-$ in volts per cm $\times 10^4$	$V-$	$E-$	E average	E calculated
2.	720	0.765	580	0.615	0.69	0.36
10.9	940	0.998	870	0.925	0.96	0.85
18.9	1110	1.18	1200	1.275	1.22	1.14
53.2	1770	1.88	1920	2.04	1.96	2.01
91.3	2350	2.50	2580	2.74	2.62	2.72
173.5	3450	3.60	3750	3.99	3.79	3.97
248.5	4250	4.51	4610	4.90	4.71	4.87
334.8	5120	5.42	5520	5.86	5.63	5.83
483.6	6660	7.08	7120	7.55	7.31	7.36
616.6	7800	8.29	8330	8.85	8.57	8.60
720.0	8730	9.28	9210	9.80	9.54	9.21
746.0	8980	9.51	9530	10.1	9.80	9.70
768.3	9100	9.67	9640	10.2	9.93	9.89

735 mm. and 754 mm. are shown in Fig. 9. These curves show quite a regular variation in the effect of pressure with a tendency toward a greater effect upon the current for negative polarity. This regularity would seem to indicate that the

discordant results obtained in the preliminary experiments were due to the presence of other factors than mere change of the pressure.

To determine, what effect if any, the confining of air in a closed tube had upon the coronal current a series of tests was run under constant pressure with various conditions as to the closing of the tube, the renewal of the air, etc. The erratic results follow no evident relations and indicate that confinement of the air has a great effect upon the coronal current and also upon the critical and visible glow voltages. Such an effect does not appear strange when one thinks of the quantities of ozone formed and possibly other products, which, when, the tube is closed, must remain inside and thus change the character of the gas to a considerable extent. It must be concluded from these tests that it is unsafe to compare results obtained in a closed tube with those obtained where there is a plentiful supply of fresh air.

TABLE 7.

EFFECT OF PRESSURE.

No. 40 B. & S. Copper Wire. Diameter 0.077 mm.
in
Tube of Diameter 4.45 cm.; length 25.0 cm.
Dry Air in Tube.
Currents in 10^{-4} amp.

Potential Difference	735 mm. +	735 mm. −	738 mm. +	738 mm. −	749.0 +	749.0 −	754.0 +	754.0 −
4000	0.00025	0.00030	0.000076	0.000051	0.000015	0.000015	0.000015	0.000015
5000	0.205	0.176	0.181	0.210	0.150	0.169	0.150	0.169
6000	0.553	0.676	0.557	0.703	0.468	0.611	0.468	0.602
7000	1.06	1.34	1.06	1.35	0.859	1.17	0.900	1.16
8000	1.76	2.28	1.73	2.32	1.38	1.90	1.53	2.02
9000	2.58	3.35	2.53	3.25	2.15	2.86	2.28	2.90
10000	3.45	4.49	3.43	4.52	2.81	3.71	2.99	3.77
12000	6.24	7.64	6.15	8.16	5.17	6.51	5.40	6.83

Positive Corona Appearance.

+	735	738	749	754
Jump	4080	4100	4100	4100
Visible	4150	4160	4110	4150

Figures for 738.00 mm. are average of three tests.

Influence of Moisture

In connection with the apparatus for the supply of dry air to the tube, an arrangement was devised whereby air could be drawn from the room through the tube. The humidity of such air was given by calculation from the readings of wet and dry bulb thermometers. Parallel sets of readings were taken from day to day of the current flowing when dry air was pumped continuously through the tube and when air from the room was sucked through before each reading. The readings and the comparative characteristics for 735 mm. pressure and relative humidity 69 per cent are shown in Fig. 10. These curves in-

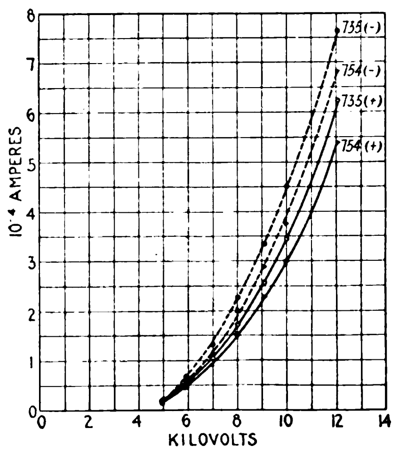


Fig. 9—Characteristic as Influenced by Pressure

No. 40 B. & S. copper wire, 0.077 mm. diameter; tube 4.45 cm. diameter, 25 cm. long; dry air at 25 deg. cent. forced through tube.

dicate a regular effect due to moisture, with a tendency for the decrease of current by humidity to be greater for negative polarity of the wire. The decrease of current by the presence of moisture is well known and these results bear out this effect.

To determine whether the presence of moisture in the air has an effect upon the critical voltage, a test was run as follows under a pressure of 736 mm. and humidity 68.5 per cent:

Air was sucked through the tube from the room and the voltage was noted at which the initial jump of the galvanometer occurred for wire positive. Then the positive glow voltage was determined and next the negative glow voltage. Then dry air was pumped through the tube and the same measure-

ments were taken. An average of two sets of readings on the uncalibrated low scale of the Kelvin voltmeter gave the results:

	Wet Air	Dry Air
Positive critical voltage	4300	4190
Positive glow voltage	4350	4260
Negative glow voltage	4275	4370

The effect of moisture is then to raise somewhat the starting point of the positive corona and act in the opposite way for the opposite polarity.

With wire negative and moist air in the tube, the discharge begins from dim spots and the discharge is of no clearly defined nature, being a mixture of sections of continuous glow and

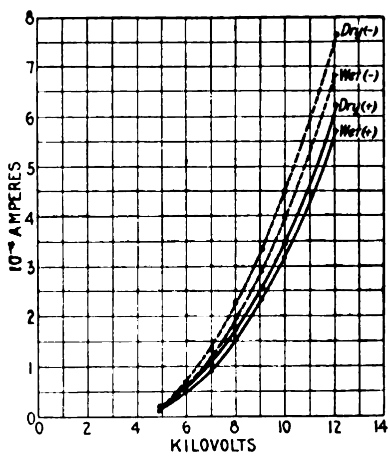


FIG. 10—CHARACTERISTIC AS INFLUENCED BY HUMIDITY

No. 40 B. & S. copper wire, 0.077 mm. diameter; tube 4.45 cm. diameter, 25 cm. long; dry air forced through tube and afterwards air from room drawn through; temperature 25 deg. cent.; humidity 69 per cent; pressure 735 mm.

bright spots, these spots being immobile. The discharge begins quite differently for the same polarity and dry air. As the voltage is increased, suddenly a bright spot will appear. Then for increasing voltage a number of spots appear and they are regularly spaced, increasing in number with the voltage. These brushes are in continual movement back and forth.

The effect of moisture on the appearance of the negative discharge was shown by the following experiment:

The tube was filled with moist air and a voltage somewhat above the critical value was impressed. A mixed discharge resulted as described above. Then a current of dry air was started through the tube and little by little the discharge cleared

up and resolved itself into a line of uniformly spaced brushes which were in continual agitation. If moist air were again admitted, the discharge resumed its former character.

With moist air in the tube and a fairly high potential difference the wire vibrates circularly for both polarities, describing a torpedo-like figure of revolution. The filling of the tube with dry air diminishes considerably the amplitude of the vibration for wire positive and stops the vibration entirely for wire negative.

Influence of Temperature

The influence of temperature upon the current for a No. 36 wire in a closed tube under a pressure of 760 mm. was determined for the range from 15 deg. to 25 deg. cent. and the results appear in Fig. 11. The lower temperature was obtained by placing cloths wet with alcohol upon the tube and directing a stream of air from a fan upon it. The curves indicate that this difference of temperature makes far more difference in the current for wire negative than for wire positive, both currents showing an increase for increasing temperature, as might be expected.

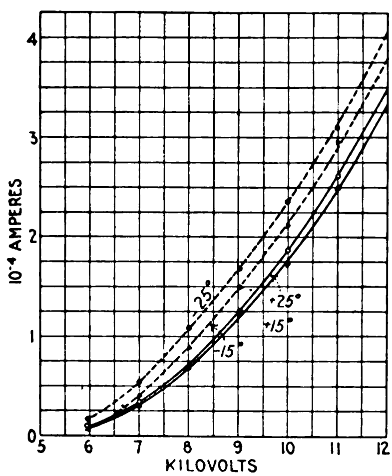


Fig. 11—Characteristic as Influenced by Temperature

No. 36 B. & S. copper wire, diameter 0.135 mm.; tube 4.45 cm. diameter, 25 cm. long; tube closed; dry air in tube under 760 mm. pressure.

Material of Wire

An attempt was made to determine the effect of the character of the surface and the material of the wire in the following way. A characteristic curve was obtained for a bright new

steel mandolin " E " string in a tube open to the air. Then the wire was dipped into a solution of copper sulphate long enough to acquire a smooth coating of copper and another characteristic was obtained. Then this wire was amalgamated and another test run. A piece of the same wire was dipped into Nitric acid long enough to roughen it without appreciably decreasing its diameter and a test was run on it. Small differences were found to exist in the characteristics but these differences were accountable for by the changes in humidity and pressure during the time of running the series of tests. It was noticed that originally polished copper wires became rough on the surface through the action of the corona.

A strong electromagnet was arranged with its poles in close proximity to a tube containing a wire on which there was corona and no effect upon the current or the appearance of the discharge could be detected, both for discharges at atmospheric pressure and reduced pressures.

Comparison with Previous Investigations

The starting point of the corona, and the current, depend on the radius of the wire, the nature, temperature, pressure and humidity of the air. The corona changes the chemical constitution of the air, hence there is great difficulty in formulating the laws. But for the beginning of the corona and relatively large radii Peek and Whitehead have found very neat laws expressed by the formula*

$$E = 31\,\delta\left[1 + \frac{0.308}{\sqrt{\delta\,R}}\right]$$

$$\delta = \frac{3.92\,p}{273 + t}$$

E is the critical electrical intensity at the surface of the wire R the radius in cm., p the pressure in cm. of Hg. and t the temperature in degrees centigrade. In Table 6 the critical electrical intensity has been calculated by means of this formula and the agreement between the calculated and the average electrical intensity or the negative value is quite satisfactory as far down as 5.32 cm. of mercury, while below this pressure discrepancies are noticeable.

*J. B. Whitehead. *The Electric Strength of Air.* TRANS. of A.I. E. E. Vol. XXXII, 1913, p. 1317.

According to Whitehead the electrical intensity E is independent of moisture content, and the current of the corona decreases by the presence of moisture. This latter statement agrees with our observations, but for the fine wires used in this investigation moisture also affects the starting point of the corona.

Pressure Due to Ionization

During the first set of experiments to determine the influence of the pressure upon the coronal current for pressures around atmospheric it was noticed that when the potential difference was applied the manometer connected to give the pressure inside of the tube showed a sudden increase of pressure. This sudden increase was most noticeable for the highest pressure and amounted to a centimeter or more. Since it was desired to keep the pressure in the tube constant a carboy was connected to the tube to act as a reservoir of large capacity and prevent the increase of pressure from reaching any noticeable value.

To investigate the connection between this increase of pressure and the potential difference impressed, a sensitive U-tube open manometer was constructed. The manometer had a bore of 2.8 mm. and contained a light mineral oil of specific gravity 0.859. It was connected to the tube, the pressure in the tube was adjusted to atmospheric, the tube was sealed up and the sudden increase of the pressure was noted for voltages from those necessary to produce the corona up to those causing the maximum jump the manometer would permit without forcing the oil out. The increases were noted for both polarities of the wire. Table 8 contains data relative to the size of the wire and tube, the readings observed and the increases of pressures reduced to terms of millimeters of mercury. Fig. 12 shows the increase of pressure plotted against potential difference.

For the positive polarity of the wire, there was no appreciable increase of the pressure until the corona appeared. When the wire was negative, the presence of a small brush or two caused the level of the columns to differ appreciably before the general discharge appeared along the wire.

The jump for wire negative was greater than for wire positive for the greater part of the range of voltage and it will be seen that the general shape of the curves is the same as that of the characteristic curves for the same size of wire as given in Fig. 11. Furthermore by comparing the numerical values of the currents and increases of pressure for like voltages it will be found that

TABLE 8.

PRESSURE DUE TO IONIZATION

No. 36 B. & S. wire. Tube 4.45 cm. internal diameter, 25 cm. long, volume 388 cu. cm
Dry air in tube, pressure 744.0 mm., temp. 26 deg. cent.
Manometer bore 2.8 mm., containing mineral oil of 0.859 specific gravity.

Wire Positive					Wire Negative				
Potential Difference	Manometer—cm. Left	Right	Diff.	mm. of mercury	Potential Difference	Manometer—cm. Left	Right	Diff.	mm. of mercury
5340	Jump barely visible.			0.000	4800	Jump barely visible			0.00
6180	12.22	13.30	1.08	0.682	6180	12.20	13.25	1.05	0.664
6680	12.19	13.59	1.40	0.885	6700	11.98	13.50	1.52	0.96
7080	11.72	13.82	2.10	1.33	7100	11.70	13.75	2.05	1.30
7440	11.48	14.10	2.62	1.66	7500	11.40	14.08	2.68	1.70
7820	11.00	14.56	3.56	2.25	7850	11.05	14.40	3.35	2.12
8200	10.80	14.79	3.99	2.52	8220	10.70	14.80	4.10	2.59
8620	10.36	15.20	4.84	3.06	8600	10.40	15.10	4.70	2.97
9200	9.75	15.80	6.05	3.83	8860	9.92	15.60	5.68	3.59
9800	9.0	16.5	7.5	4.74	9400	9.3	16.2	6.9	4.36
10400	8.3	17.3	9.0	5.69	10500	7.6	17.8	10.2	6.45
10840	7.4	18.1	10.7	6.76	11000	6.8	18.5	11.7	7.39
11300	6.6	18.8	12.2	7.71	11460	5.9	19.4	13.5	8.53
12200	4.8	20.3	15.5	9.80	11940	4.5	20.7	16.2	10.2
12900	3.3	22.1	18.8	11.9	12640	2.5	22.3	19.8	12.5
13840	1.1	24.3	23.2	14.7	13520	0.4	24.2	23.8	15.0
14200	0.2	25.2	25.0	15.5					

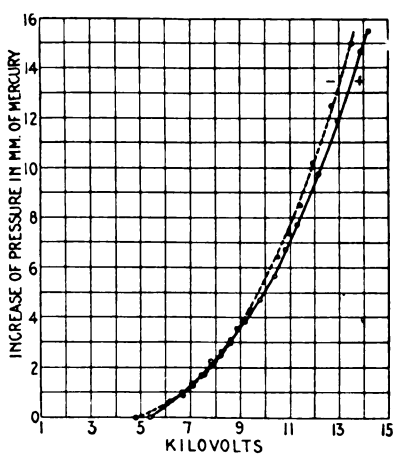


FIG. 12—INCREASE OF PRESSURE DUE TO IONIZATION

No. 36 B. & S. copper wire, diameter 0.135 mm.; tube 4.45 cm. diameter, 25 cm. long. Curves show sudden increase of pressure in closed tube when potential difference is applied. Dry air, pressure 744 mm.

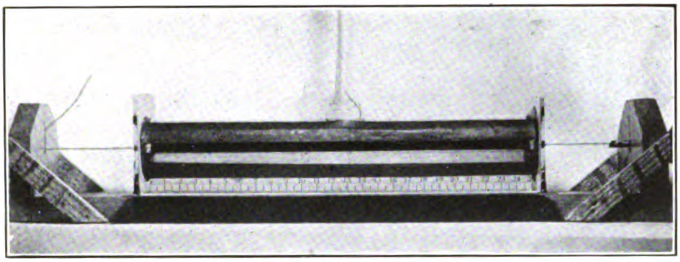
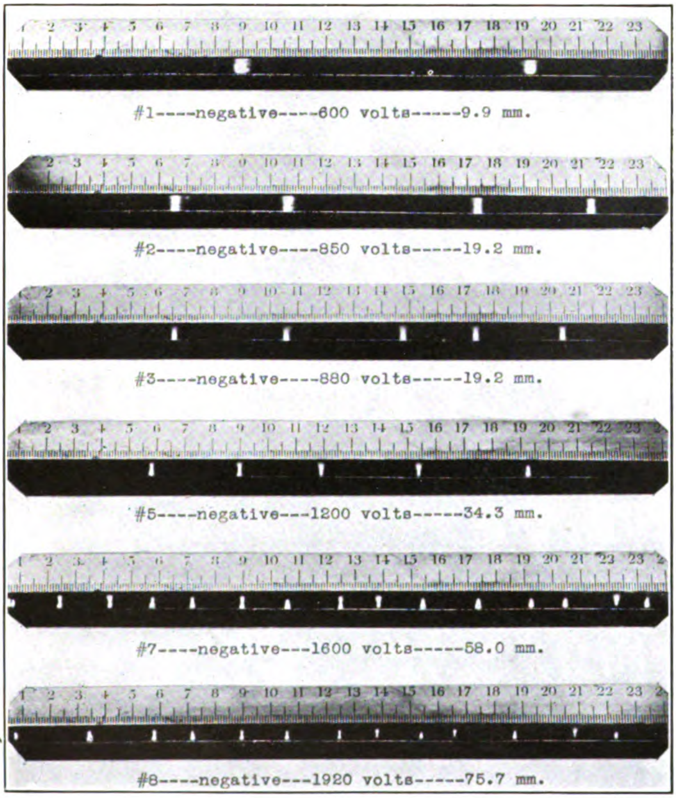


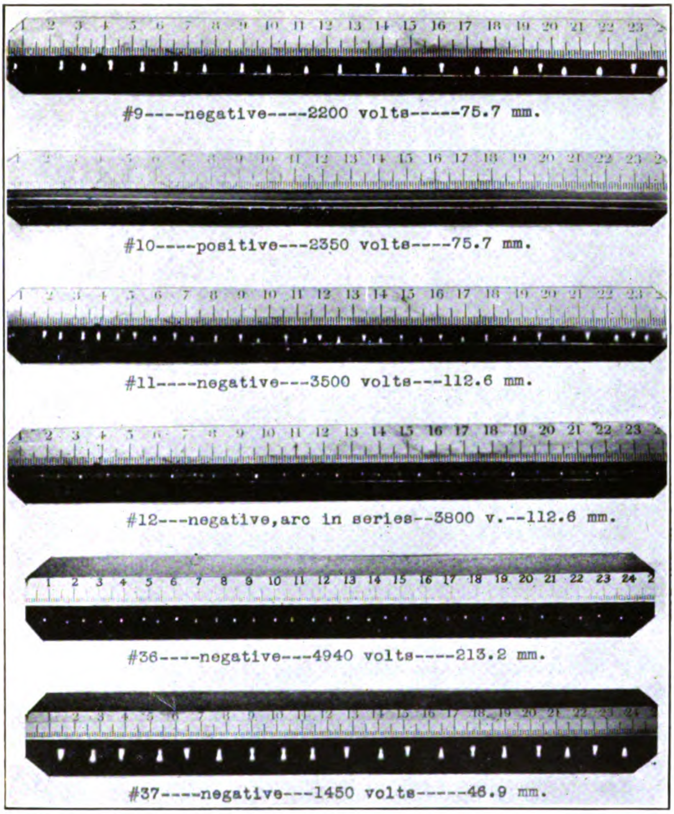
FIG. 13—TUBE USED FOR PHOTOGRAPHS [FARWELL]

B. & S. wire, diameter 0.26 mm.; tube 3.5 cm. diameter, 25 cm. long; with longitudinal slit 0.6 cm. wide.



Series No. 1—Pressure in tube and potential difference varied. [FARWELL]

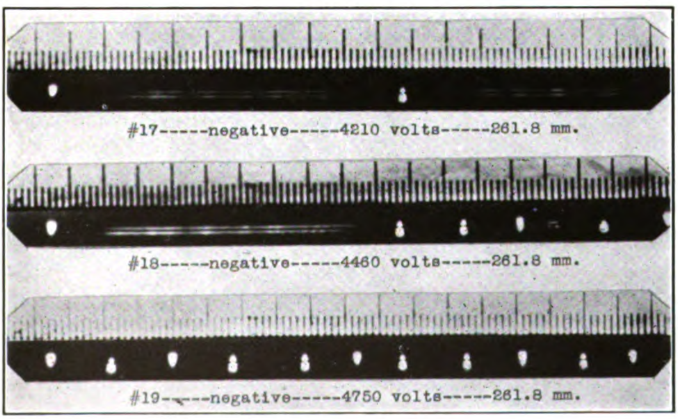
FIG. 14—CHANGES IN NATURE OF ISOLATED BRUSH DISCHARGE WITH POTENTIAL DIFFERENCE AND PRESSURE



[FARWELL]

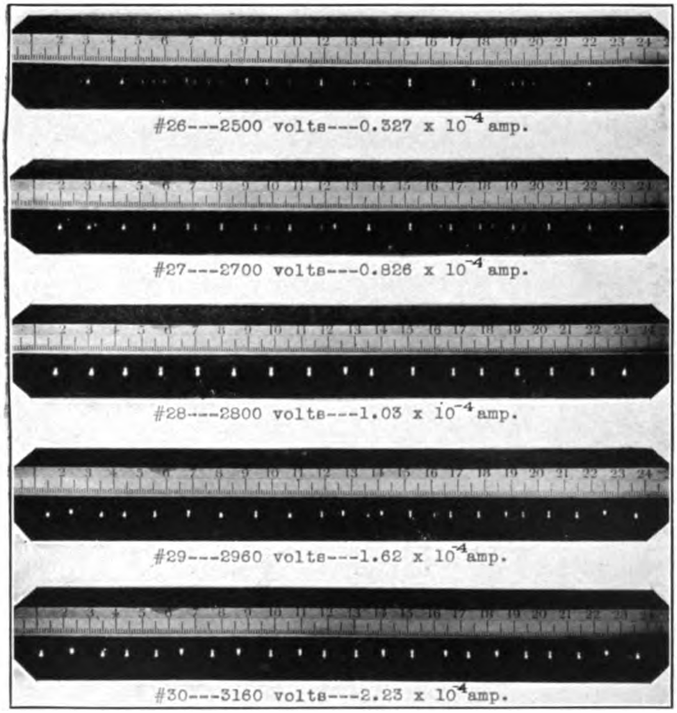
Series No. 1 (continued)—Pressure in tube and potential difference varied.

FIG. 15—VARIOUS FORMS OF DISCHARGE AT REDUCED PRESSURES



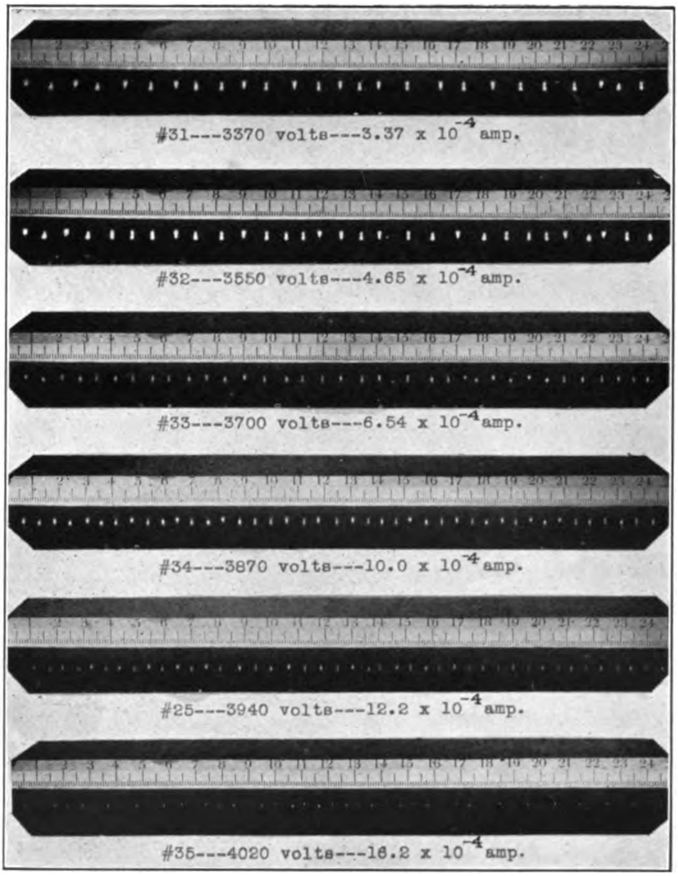
Series No. 3—Wire negative—pressure constant. [FARWELL]

FIG. 16—EVOLUTION OF NEGATIVE ISOLATED BRUSH DISCHARGE FROM CONTINUOUS GLOW



Series No. 5—Wire negative—pressure constant. [FARWELL]

FIG. 17—VARIATION OF NUMBER OF BRUSHES WITH POTENTIAL DIFFERENCE—GLOW VOLTAGE 2440



[FARWELL]

Series No. 5 (continued)—Wire negative—pressure constant at 119.6 mm.

FIG. 18—VARIATION OF NUMBER OF BRUSHES WITH POTENTIAL DIFFERENCE

they are proportional. This shows that the increase is an ionization phenomenon, for if the sudden increase were due to the heating effect of the current we would expect the increases to vary as the square of the currents instead of the first power.

The theory of ionization would lead one to expect such a jump when the gas is suddenly ionized; some particles in the gas would be split up by collisions and each of the constituent parts would act as a separate molecule as far as its contribution to the total pressure is concerned.

This ionization pressure might serve as a principle upon which to build a high-tension voltmeter, for if such a tube were once calibrated, the indications of the manometer would give a measure of the potential difference impressed.

Discontinuous Brush Discharge

As already mentioned, at low pressure and negative polarity of the wire, the discharge took the form of isolated beads or brushes disposed with approximate regularity along the wire. In order to be able to see the wire broadside a glass tube was lined with a piece of sheet brass of such a width that a longitudinal slit was left along the tube thus permitting inspection of the discharge along the central wire. The glass tube was closed at the ends by glass plates with central holes drilled through them. The wire passed through these holes and could be tightly stretched by means of a thumbscrew. The dimensions of the apparatus are given in the illustration, Fig. 13. This picture shows the branch tube through which the air could be exhausted and a wire along this tube connecting with the brass sheath. The holes around the wires where they passed through the glass plates were stopped by means of soft wax, the tube was exhausted and then filled with dry air by admitting air from the room through the drying apparatus mentioned previously. Then various forms of discharge were produced and photographs taken of them.

Series 1, Figs. 14 and 15, was taken to give an idea of the development of the discontinuous discharge from a few intensely bright beads to a series of small brushes spaced with considerable regularity along the wire. For the lowest pressures the beads consist of a bright cylindrical core along the wire, which core is surrounded by a narrow dark space, enveloped in turn by a purple glow of relatively large diameter. For increasing pressure the central core contracts to a point and the discharge instead of surrounding the wire to form a bead, starts from this bright

point and spreads out fan-like in a plane at right angles to the wire. For still higher pressures the fan seems to shut up and finally degenerates to a small brush. For all of the illustrations in Series 1, except No. 36 and No. 37, the wires was not stretched tightly and therefore the regularity of spacing of the brushes is not very great. The two photographs from which these illustrations were made were taken with the wire tightly stretched, and the regularity of spacing is apparent. No. 10 shows the typical uniform positive glow. No. 12 shows the effect upon the brush discharge of inserting an arc in series with the tube.

Series 3, Fig. 16, shows the evolution of the isolated brush form

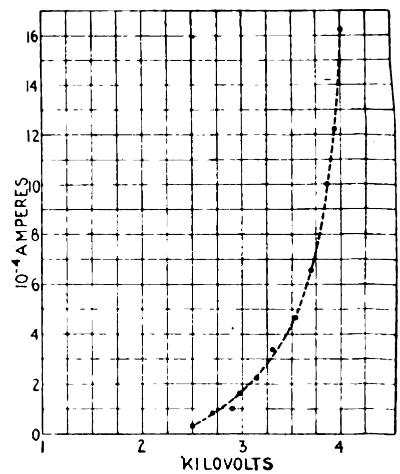


Fig. 19—Negative Characteristic

No. 30 B. & S. copper wire, 0.26 mm. diameter; slit tube 3.5 cm. diameter, 25 cm. long; pressure in tube 119.3 mm.

of negative discharge from a continuous glow. For a potential difference just above the critical value, the negative wire was enveloped by a more or less hazy continuous discharge. Keeping the pressure in the tube constant and raising the voltage slightly causes some of the glow to turn into brushes and with increasing voltage all of the glow is converted into the uniformly spaced form of brush discharge. Sometimes conditions can be arranged so that the brushes appear one after another with apparently no change in the conditions.

Series 5, Figs. 17 and 18, was taken to find, if possible, some definite relation between the number of brushes and the potential difference for a given pressure in the tube. The increase of

the number of brushes with the voltage and the regularity of spacing of the brushes is apparent. Photographs were taken at voltages where the distribution of brushes was most regular. For the highest voltages, the brushes were in constant movement back and forth along a short path, and to secure a good picture it was necessary to make the time of exposure quite short.

Fig. 19 is the characteristic curve for the currents and voltages employed in Series 5. This graph shows the rate of increase of current with voltage to be very great at the highest voltages employed.

Fig. 20 shows the number of brushes as a function of the potential difference. In some of the photographs some of the brushes were seen to be smaller than the rest and for the plotting

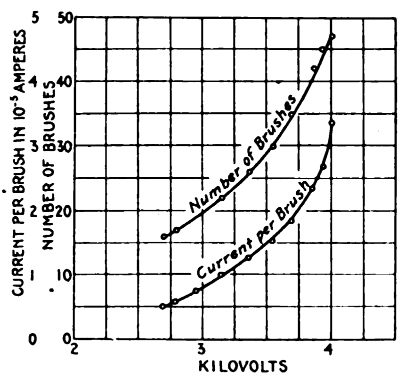


FIG. 20—NUMBER OF BRUSHES AND CURRENT PER BRUSH AS FUNCTION OF POTENTIAL DIFFERENCE

No. 30 B. & S. wire in slit tube; pressure 119.3 mm.; wire negative.

of the graph the estimated equivalent number of full-sized brushes was taken. Evidently the number of brushes is some well-defined function of the potential difference. Between the voltages at which the arrangement of brushes was most regular, there seemed to be a transition period in which there were many little brushes in addition to the larger ones. An increase of voltage would then produce a set of full-sized brushes.

The lower curve of Fig. 20 gives the variation of the current per brush on the assumption that the total current is carried by the brushes.

EFFECT OF SHORT ARC UPON DISCHARGES

Nature of the Phenomenon. Series No. 2, Fig. 21, shows the effect of a short arc in series with the tube upon the character of

the positive and negative discharges for a constant pressure in the tube and an approximately constant difference of potential.

The typical quiet bluish positive discharge shown in No. 13 is changed to No. 14, which is more brilliant, of a purple tinge and greater in diameter. In addition its boundaries seem more ragged.

The typical discontinuous negative discharge has its character changed most markedly by the introduction of the arc. No. 16 shows the changed discharge; it seems to be made up of two effects superimposed upon each other. The arc evidently sets up high frequency oscillations in the circuit and an alternating effect is superimposed on the direct current phenomenon. To test whether this theory was correct, the following experiment was tried:

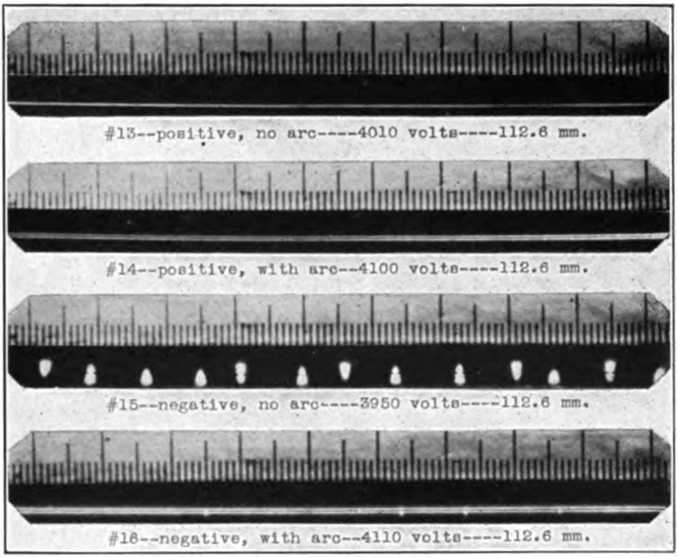
A two-mf. condenser was connected in parallel with the tube, and with the arc in circuit, a potential difference was impressed upon the tube of a value high enough to give corona. The appearance was then as though there were no arc in the circuit. The high frequency component of the current prefers rather to take the path through the condenser than to go across the air gap.

It took an appreciable time for the condenser to become fully charged and during this time occurred the evolution of the brush discharge from the continuous glow in the manner mentioned above, except that the time of the process was prolonged.

Upon disconnecting the charged apparatus from the source of potential, the discharge through the tube persisted for some seconds due to the discharge of the condenser through it. As the voltage of the condenser fell, the number of the brushes became fewer and their brightness diminished until they vanished. During this discharge, the brushes maintained quite a regular arrangement.

By assuming fair values for the electrical constants of this discharge circuit, it is easy to calculate that the discharge of the condenser must be of the continuous type. This being the case, it is evident that the negative discontinuous discharge must be essentially a direct current phenomenon.

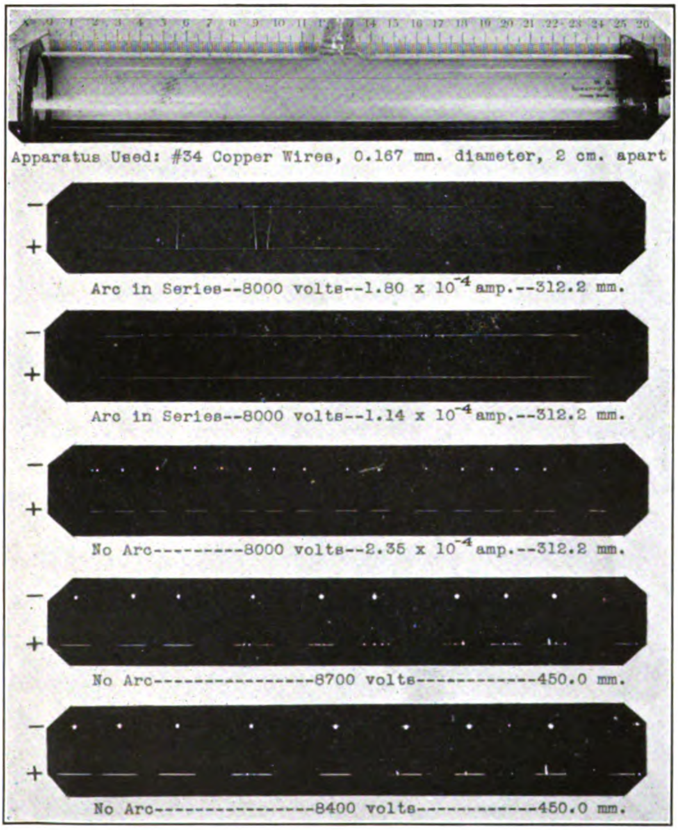
It should be remarked that the values of current given for the cases where an arc is in circuit represent only the continuous components, since the galvanometer deflection is unaffected by the alternating components. There is hardly another phenomenon which shows so directly the difference between positive and negative electricity as the foregoing illustrations.



Series No. 2. [FARWELL]

FIG. 21—EFFECT OF SHORT ARC IN SERIES ON NATURE OF DISCHARGES

No. 30 B. & S. wire in slit tube; pressure constant at 112.6 mm.



Series No. 6. [FARWELL]

FIG. 22—TWO PARALLEL WIRES—REDUCED PRESSURE

Nevertheless the question may be raised as to whether the isolated brush form of discharge may not be due to oscillations in the circuit. In order to make it clear that this is essentially a direct-current phenomenon, there follow some experiments and arguments which support this view.

The appearance of the brushes and the current indicated by the galvanometer are constant for a given voltage, no matter what combination of machines are used as the source of potential. One of the sets may be used and the appearance of the spots and the voltage and current noted. Then if the other set be used to give the same voltage with a different number and speed of machines, the same results are obtained. If there were oscillations set up perhaps by sparking at the brushes, we would not expect this agreement.

Mention has been made before of the effect of the introduction of a condenser in parallel with the tube. To test whether the current sent through the tube by the condenser in discharging was direct or oscillatory, another experiment was performed. The condenser was connected across the positive and negative bus-bars to which the generating apparatus was connected through the water resistance. Then a switch connecting the machines to the busbars was closed as was also a switch leading to the tube. The deflection of the galvanometer was noted and the appearance of the brushes. Then the generator switch was opened and the condenser discharged through the tube and the galvanometer. After the switch was opened, the galvanometer deflection gradually decreased, the rate of the decrease being slower and slower as the discharge proceeded. The opening of the switch caused no immmediate change in the brushes, only the gradual change already noted. That the discharge of the condenser must be continuous is shown by the deflection of the galvanometer and it can be further proved by a rough calculation. Assuming the resistance of the cylindrical field as given by E/I and taking a set of values of E and I for the comparatively low pressures at which the brushes are best formed, we obtain $R = 1.83 \times 10^6$ ohms. Assuming the very large value of 0.1 henry for the inductance of the circuit, and the approximate value of 2 mf. for the capacity, we find that R is about 4.1×10^4 times as great as $\sqrt{4L/C}$ and hence it is clear that the condenser discharge must be of the continuous type.

By running wires from the terminals of an induction coil

to the central wire and the tube and then adjusting the discharge points on the coil to such a distance that a silent discharge took place between them, it was possible to obtain an almost uniform hazy glow along the wire. But no effect could be obtained like the uniformly spaced brush discharge.

It is well known that an arc is the source of electrical oscillations and it has been shown by a previous figure that a short arc in series with the tube disturbs the brushes due to the direct current by the superposition of an alternating current effect so that the glow becomes more or less uniform and the difference in the appearance of the glow for different polarities becomes much less. So the introduction of an oscillatory current acts to suppress the isolated brush form of discharge and not to cause it.

It should be stated here that Peek* by a stroboscopic method has also observed "more or less evenly spaced beads" on the negative wire when there was corona between parallel wires caused by an alternating difference of potential of 80,000 volts at atmospheric pressure. The wires used by Peek were 0.168 cm. in diameter, spaced 12.7 cm. apart.

Corona between Parallel Wires

Phenomena at Reduced Pressures. Two No. 34 wires, 0.167 mm. in diameter, were arranged parallel and two centimeters apart inside of a glass tube as shown in Fig. 22 and photographs were taken of the discharge between them at reduced pressures. The three lower illustrations of Fig. 22 show the typical isolated brush discharge on the negative wire with corresponding luminous section of the positive wire. The negative brushes had a brilliant nucleus with a fainter glow spreading out from it. For lower pressures than those for which the photographs were taken, the discharge became more brilliant; the brushes spread farther apart and increased in size. Each section of positive glow was usually of uniform brilliance. But for comparatively low pressures and high voltage, these positive sections became somewhat discontinuous, bright spots being mixed in with the uniform glow.

The introduction of a short arc in series made a marked change in the nature of the discharge. Both wires were more or less completely covered with a nearly uniform glow and there was no longer any marked difference between positive

*Proc. A. I. E. E., Vol. XXXI, No. 6, p. 1123, and Plate LXV.

and negative. The brilliancy of the discharge depended upon the fatness of the spark. With the arc in series, low pressures and a relatively high voltage, the discharge between the wires resembled a sheet of luminuous rain. An intermediate effect showed bluish streamers between the wires.

It should be remarked that the values of current given for the cases where an arc was used are only the continuous components of the current.

Phenomena at Atmospheric Pressures. Two No. 36 wires were stretched over hard rubber bridges so as to be parallel and three centimeters apart and a characteristic test was obtained for the discharge between them. The dimensions of the wires,

TABLE 9.

Two Parallel No. 36 Wires—0.135 mm. diam. 36.2 cm. long and 3.0 cm. apart.

Temperature	26.5
Relative Humidity	43.0 per cent
Barometric Pressure	749.0

Potential Difference	Deflection in mm.	Shunt Factor	Current in 10^{-4} amp.
6000	0.3	1.0	0.000015
6400	0.5	1.0	0.000025
6500	Critical	Voltage	
7000	125.0	1.0	0.00634
8000	37.0	12.832	0.0241
9000	75.0	12.832	0.0488
10000	30.0	128.32	0.195 Glow sets in
12000	198.0	128.32	1.29
14000	49.0	1283.2	3.19

$F = 5.07 \times 10^{-9}$ amp. per mm. deflection.

the atmospheric conditions and the data for a characteristic curve are given in Table 9. A sudden increase of the deflection of the galvanometer marked the critical voltage as in the case of former tests with wires in a cylindrical field. It was noted in this test that there was a considerable current flow between the wires before there was any indication of a glow. At 10,000 volts a flickering glow along the positive wire gave the first indication of a general glow.

When the visible discharge was fairly started, it took the form of a uniform continuous glow along the positive wire and a fairly regular arrangement of brushes along the negative wire. This discharge was examined on a day when the humidity was considerably greater and it was noticed the negative discharge had

lost all appearance of a regular distribution and there was more of a continuous glow effect.

It was noticed that the negative wire bowed in toward the positive and that the positive bowed away from the negative. This effect was noticed in one of the preliminary experiments with an influence machine.

When the wires were purposely made rather slack in order to intensify the effect it was found that the positive wire vibrated strongly with a circular motion and that the negative was motionless. If the polarity of the wires was reversed, the phenomenon reversed also and it was still the positive wire which vibrated.

Exploration of Field between Parallel Wires. A glass tube with a platinum contact wire projecting axially from its tip was fixed into a wood block in such a manner that when the block was moved across a board beneath and parallel to the plane of the wires, the platinum contact point moved in the plane of the wires. By means of a scale fixed across the board perpendicular to the direction of the wires it was possible to set the contact point at any desired position between the wires. When the ground terminal of one of the electrostatic voltmeters was connected to the grounded negative wire and the high-tension terminal was connected to the contact point it was found that the voltmeter deflected when there was a current flow between the wires and the contact point was in the neighborhood of the wires. So long as there was no current flow between the wires there was no deflection.

Figs. 23 and 24 show the curves for field distribution as plotted from the data, and also the distribution of the electrostatic field between the wires as calculated from the formula for the electrostatic field on a line between the axes of parallel wires. If P denote the point where the potential is desired, A and B the inverse points of the circular sections of the wires and q represents the charge per unit length of one wire, the potential V at the point is given by

$$V = -2q \log (AP/BP)$$

Sufficient accuracy was obtained for the purpose in hand by taking the inverse points as at the centers of the wires.

An examination of the curves for the actual distribution of the field discloses the fact that there are large anode and cathode falls of potential, the anode fall of potential being the greater for the two lower potential differences. For these also the

actual field departs widely from the electrostatic. For the 12,000-volt curves the actual and electrostatic fields become more alike.

The field is distorted through ionization, because the positive ions are driven toward the negative wire and form a layer of positive electricity round about the negative wire. Hence there results a very large fall of potential around this wire. Around the positive wire there is an accumulation of negative electricity and hence there is a fall of potential here also. But the positive and negative ions are of different size and mobility, and therefore the

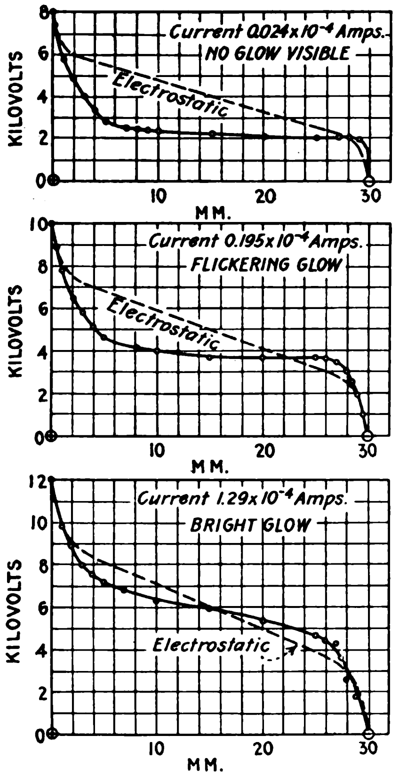


FIG. 23—DISTRIBUTION OF THE POTENTIAL BETWEEN TWO PARALLEL WIRES 0.135 MM. IN DIAMETER, 30 MM. APART

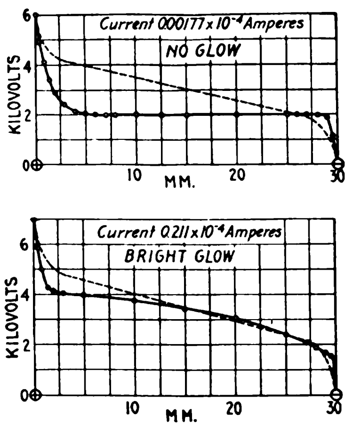


FIG. 24—DISTRIBUTION OF THE POTENTIAL BETWEEN TWO PARALLEL WIRES 0.052 MM. IN DIAMETER, 30 MM. APART

distortion of the field about the positive wire is different from that around the negative wire.

Notes on Test. At voltages a little above the critical voltage there is a noticeable lag of corona behind e.m.f.; in the extreme case this lag amounted to a second or so. Spots on the negative wire appear first, then the general glow, which appeared to move along the positive wire from the end leading to machines

The negative glow is by far the brightest and is inclined toward a purple, while the positive glow is blue. With the high humidity, there was no regularity in spacing of brushes, and much continuous glow on the negative.

An attempt was made to see whether after corona was formed and then the potential difference was lowered, below the critical value, the corona would persist. So far as could be determined the corona stopped when the critical voltage was reached.

At 13,000 volts potential difference a marked electrical wind was noticed proceeding from the wires. It was strong enough to be noticed on the face when held a few inches from the wires.

At this voltage, the negative wire was vibrating with a barely perceptible movement, while the vibration of the positive wire was excessive. And also at this voltage, the negative corona

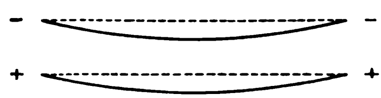


Fig. 25

seemed in more rapid movement than before; the spots were most of them oscillating back and forth. The positive wire was vibrating in a circular path.

With wires bowed as shown in Fig. 25, glow and increase of current appeared almost simultaneously, while with wires used in previous parallel wire test, the jump took place long before the glow appeared.

This investigation was carried out in the Laboratory of Physics at the University of Illinois under the direction of Dr. Jakob Kunz, Assistant Professor of Physics. To him, to Professor E. B. Paine of the Electrical Engineering Department and to Professor A. P. Carman of the Department of Physics, the author wishes to acknowledge his indebtedness for many helpful suggestions as to the conduct of this work.

Presented at the Pacific Coast Meeting of the American Institute of Electrical Engineers, Spokane, Wash., September 10, 1914.

THE ELECTRICAL OPERATION OF THE BUTTE, ANACONDA & PACIFIC RAILWAY*

BY J. B. COX

ABSTRACT OF PAPER

Of a total of ten notable instances of steam railway electrifications in this country, the Butte, Anaconda & Pacific was the first if not the only one in which the prime cause for the change in motive power was an expected decrease in operating expenses sufficient to give immediately a satisfactory earning on the new investment of capital required for the improvement.

The preliminary investigations and estimates had indicated a probable annual saving amounting to about 17.5 per cent on the total investment, of which 11 per cent was expected to result from the partial substitution of electrical energy, costing about 0.552 cent per kw-hr. at the secondaries of the substation transformers, for coal of 12,250 B.t.u. calorific value and costing $4.25 per ton delivered. The remaining 6.5 per cent was expected from reduced cost of locomotive maintenance, engine house expense and enginemen's wages.

On this prospect, an expenditure of $1,201,000 was made in the electrification of 90 miles of track and in replacing 22 steam locomotives by 17 electric locomotive units which now operate about 80 per cent of the total locomotive-miles.

The actual results as indicated by the first six months of full electrical operation show the total net saving in operating expenses to be at the rate of $242,299.12 per year or an earning of 20.02 per cent on the investment, of which the decrease in the cost of coal and power is 12.5 per cent.

Other savings are due to decreased cost of locomotive maintenance, engine house expenses, lubricants, supplies and trainmen's wages.

The average tons per train hauled by the electric locomotives has increased 33 per cent, the average time per trip decreased 30 per cent, the delays to traffic decreased 41 per cent, the number of trains decreased 25 per cent and the number of engine and train crews decreased 25 per cent.

THE AUTHOR wishes, at the outset, gratefully to acknowledge the assistance of Mr. H. A. Gallwey, general manager, Butte, Anaconda & Pacific Railway Company. It is through his coöperation and effort that the operating data given herein are made available. Information of this character has seldom been published and that it is here given to the public is a tribute to the broad minded policy of the railway company.

The Butte, Anaconda & Pacific Railway was built in 1892

*Manuscript of this paper was received September 16, 1914.

principally for the purpose of conveying the ore from the mines at Butte to the Washoe smelter which had been located at Anaconda, 26 miles west of Butte, where an abundant supply of water, so necessary in the reduction of the ore, was obtainable. The tracks connecting Butte and Anaconda constitute the main line, which is approximately 25.7 miles in length. As the mines are mostly around the top of Butte Hill and the shafts through which the ore is hoisted to the surface are scattered over a considerable area, yards were built at a convenient point on Butte Hill for the concentration of the cars containing the ore from these shafts, as well as to serve as a distribution point for the supplies to the mines, and a branch locally known as the Missoula

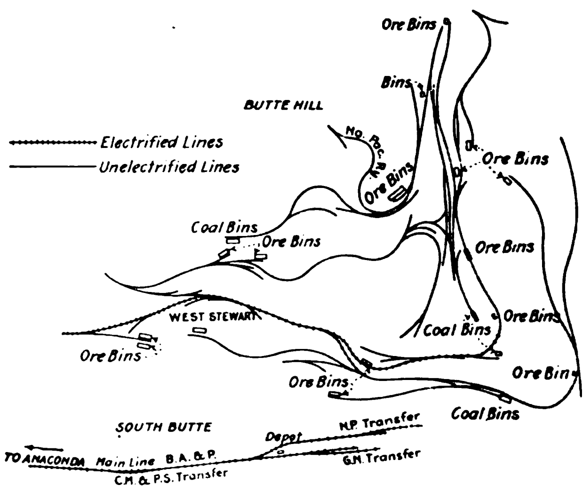
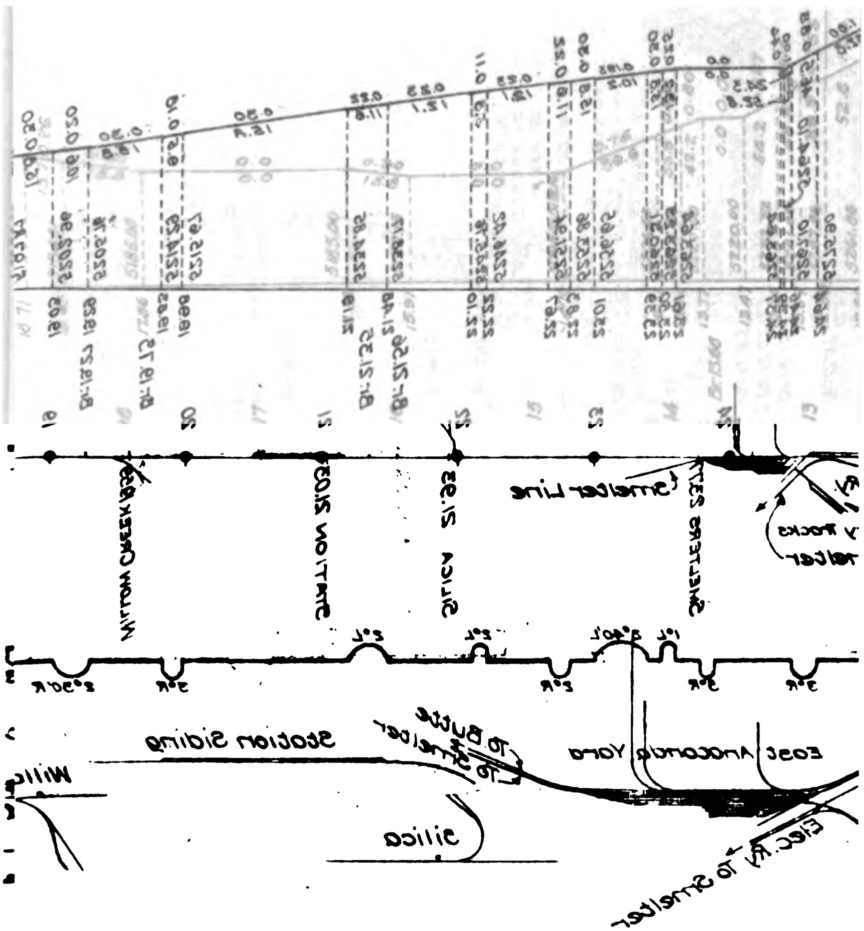
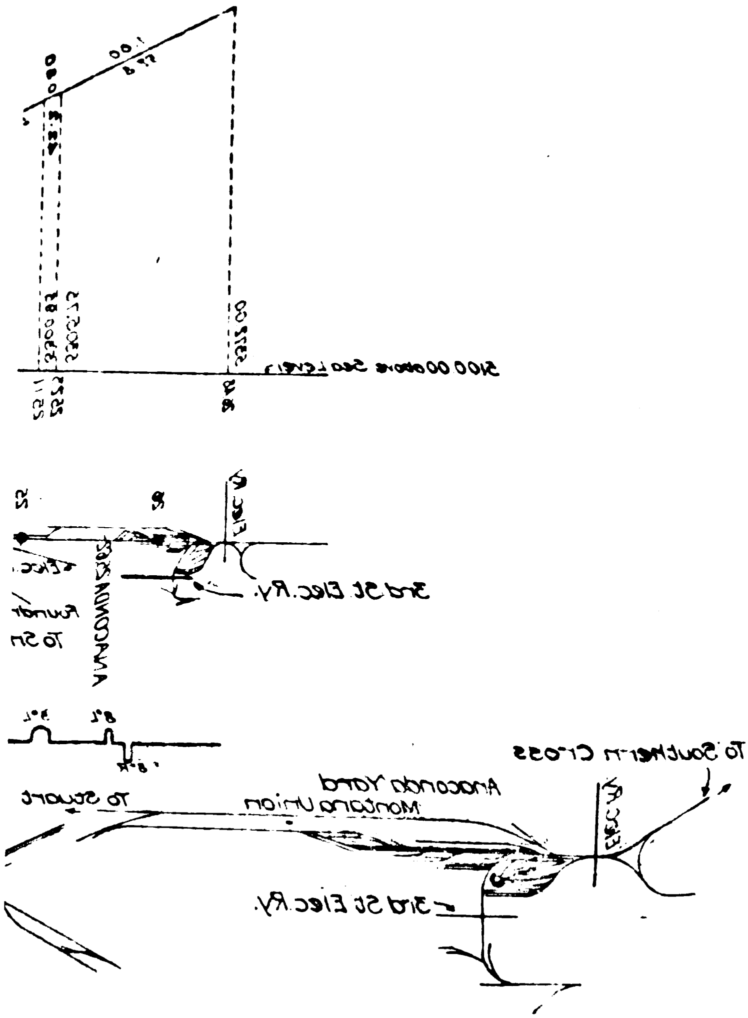


FIG. 2—OUTLINE MAP OF RAILWAY LINES ON BUTTE HILL FOR COLLECTION OF ORE AND DELIVERY OF SUPPLIES

Gulch line, Fig. 2, was built from these yards to connect with the main line at Rocker, where yards were also established.

Since the concentrator at the smelter is also on a hill at an elevation of approximately 340 ft. above the main line, it was advisable to establish another yard at East Anaconda from which to distribute the ore and other supplies to the different centers on Smelter Hill. The lines from these yards at East Anaconda to the smelter are known as the Smelter Hill lines, the longest branch of which is that leading to the concentrator, which is about 7¼ miles in length. Two spurs lead off from this main track, one to the stock bin yards and the other to the copper tracks, Fig. 4.





5100.00 above Sea Level
3rd St. Elec. Ry.
Anaconda
To Sm
Anaconda Yard
Montana Union
To Southern Cross
To Stuart
3rd St Elec. Ry.

From the Butte Hill yards spur tracks radiate about Butte Hill to the shafts of the various mines and other points where supplies are to be delivered, Fig. 1. Bins for receiving ore as it is hoisted from the mines are located near each shaft and from these bins the ore is loaded into hopper-bottom steel ore cars of 50 tons capacity each, these loaded cars being delivered to the Butte Hill yards, where they are made up into trains and taken down to the Rocker yards, where they are made up into still larger trains and taken over the main line to East Anaconda yards. Here the trains are broken up to be transported in smaller units up Smelter Hill to the concentrator yards. Thus practically all of the ore cars are handled by five different engine crews between the ore bins at the mines and the receiving bins at the concentrator.

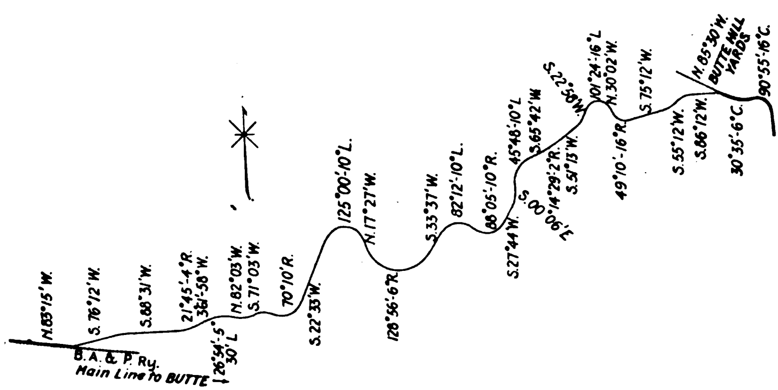


FIG. 3—MAP OF MISSOULA GULCH LINES, ROCKER TO BUTTE HILL YARDS, BUTTE, ANACONDA AND PACIFIC RAILWAY

A total of 27 steam locomotives was owned by the railway company, classified as follows

Switching	7
Consolidation	8
Mastodon	10
Passenger	2

The coal used on the steam locomotives was obtained from the mines at Diamondville, Wyoming, and had to be transported approximately 395 miles for delivery to the bins of the railway company, at which point its average cost was approximately $4.25 per ton.

The machinery at the mines and the smelter had mostly been electrified, and the results had been so satisfactory that the

railway company had a study of their conditions made for the purpose of investigating the advantages that might be expected from the electrification of their lines, the result of which was the placing of a contract in December, 1911, for the electrical equipment of the main portion of its line, consisting of the main line, spurs and yards between Butte and Anaconda, the Missoula Gulch line between Rocker and Butte Hill yards and the Smelter Hill lines. Owing to local conditions on the spur tracks leading to the various mines from Butte Hill yards, it was thought advisable not to electrify these until a later date.

Three of the steam switching locomotives listed above were

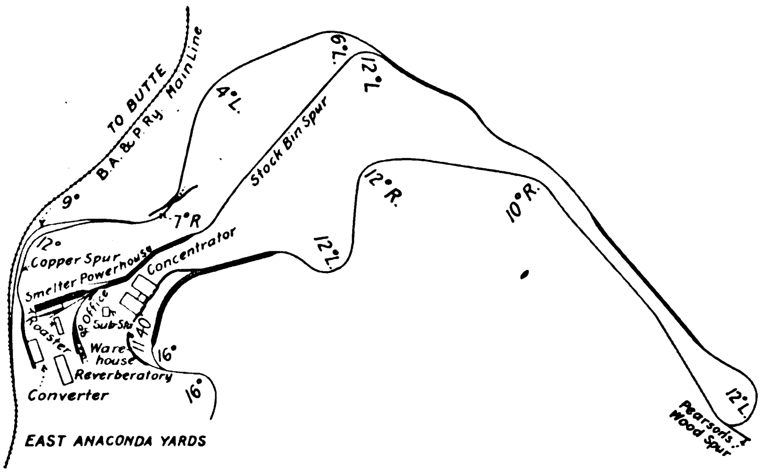


FIG. 4—MAP OF SMELTER HILL LINES, BUTTE, ANACONDA AND PACIFIC RAILWAY

used daily on Butte Hill collecting ore from and delivering supplies to the various mines from the Butte Hill yards.

The Georgetown extension to Southern Cross, 22.9 miles west of Anaconda, was underway at the time, but as it was expected that a few trains per week would take care of the traffic over this branch for some time, its electrification was not seriously considered in the original study.

It is fair to assume that a vital consideration leading to the electrification of this railroad was the rapid development and physical consolidation of a network of hydroelectric power plants in the territory tributary to the railroad.

A contract for the power for the operation of the road was made with the Great Falls Power Company, which, operating under

the same management and in physical connection with the system of the Montana Power Company, was enabled to guarantee an ample supply of power at all times with exceptional freedom from interruptions to service, and at a reasonably low price.

The tracks recommended to be electrified totaled approximately 90.5 miles, all of which are supplied with power from two substations, one being located in the Missouri River Power Company substation on Butte Hill and the other in the substation building on Smelter Hill, from which electrical power for operating the machinery there is distributed. At each of these substations there was vacant space for the location of the extra apparatus required for the operation of the railway, and the transformer capacity already installed at each place was

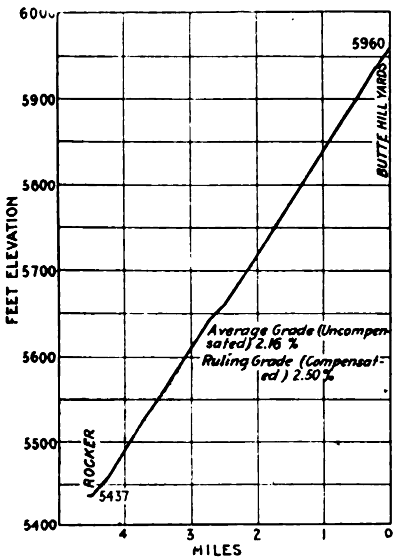


Fig. 5—Condensed Profile of Missoula Gulch Line

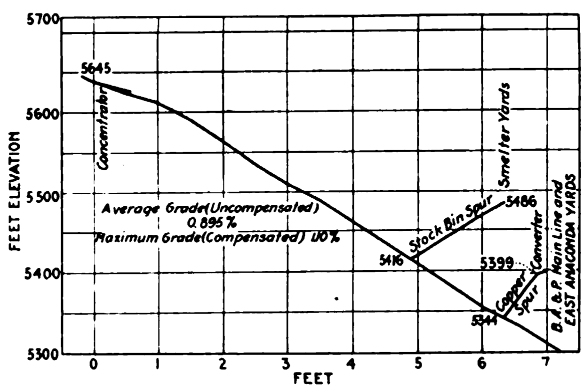


Fig. 6—Condensed Profile of Smelter Hill Lines

sufficient to meet the extra demand required for the operation of the railway.

The Anaconda substation is connected with the Butte substation by three high-tension trunk lines. The Butte substation

receives power over five separate transmission lines from six hydroelectric stations of the following rated capacities:

Big Hole Development	....	3,000 kw.	60 ft. head.
Madison River "	....	9,000 "	110 " "
Canyon Ferry "	....	7,500 "	35 " "
Hauser Lake "	....	14,000 "	60 " "
Black Eagle "	....	3,000 "	44 " "
Rainbow "	....	21,000 "	110 " "
Total	....	57,500 "	

There is also now under construction the Great Falls Development, 60,000 kw., 155-ft. head. Fig. (7.)

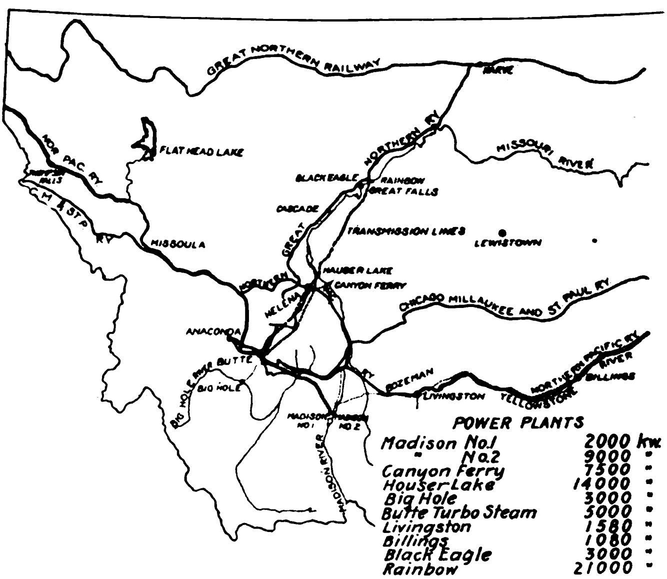


Fig. 7—Plants from which Electric Power is Purchased by the Butte, Anaconda and Pacific Railway.

All these plants are on the Missouri River water shed, all operate with free interchange of power, and all, except the first, are located in a series below the new Hebten reservoir, now being completed on the head waters of the Madison river, with an available capacity of 300,000 acre-ft. of storage.

The individual plants are also provided with storage reservoirs aggregating 125,000 acre-feet of total available storage capacity. All of these reseıvoirs operating under one control are capable of developing from stored water alone, in addition to the power otherwise available from the natural flow of the river, the

equivalent of about 100,000 electrical horse power for a period of 100 days.

In view of this development, the generally recognized advantages of purchasing electric power from a large operating system instead of developing the required power independently were readily apparent in the case of the B. A. & P. railway. The railroad was relieved of all first cost of development and transmission of power and of all operating expense up to the point of delivery of power to the two substations. The cost of the delivered power is less than it would have been from an independent development, because the power company is enabled to operate large generating stations at relatively high load factor (about 75 per cent), whereas an independent plant purely for the operation of the railway would have to operate in this case at about 30 per cent load factor, with correspondingly high fixed and operating charges per kilowatt-hour actually used. The large number of generating stations and complete network of transmission lines already developed by the power company afford ample insurance against interruption to railroad service due to possible failure of any part of the generating or transmitting system of the power company, and the enormous inertia or flywheel effect of the motor loads connected to the power system maintain extremely steady speed and voltage under the most extreme variations of load on the railroad.

The original equipment of each substation was practically the same, consisting of two 1000-kw., three-unit motor-generator sets with the necessary starting and operating devices. Each motor-generator set consists of a 1450-kv-a., three-phase, 60-cycle, 720-rev. per min. synchronous motor coupled direct to two 500-kw., 1200-volt direct-current generators, one at either end, the two generators operating in series and supplying 2400-volt direct current to the trolley lines. The generators are compound wound and have compensating pole face windings as well as commutating poles. The series fields are connected on the grounded side of the armature while the main fields are separately excited from a 125-volt circuit. The motor-generator sets are capable of carrying overloads up to three times normal load momentarily, and 50 per cent overload for two hours. The value of this characteristic will be appreciated when it is noted that each electric locomotive unit has a continuous rating of approximately 900 kw., almost equal that of a single motor-generator set, and frequently 16 of the

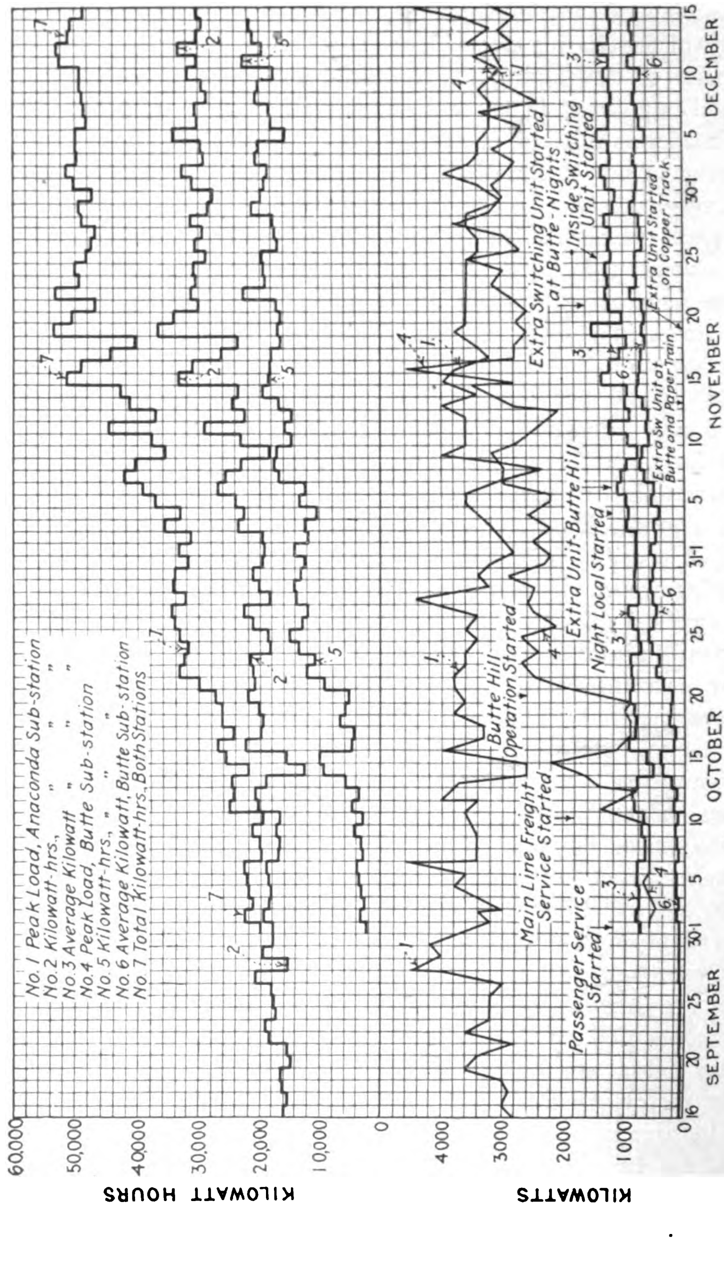


FIG. 8—DIAGRAM SHOWING SUBSTATION LOADS

17 units are in service simultaneously, 11 of which are concentrated at the Anaconda end at intervals.

Seventeen 80-ton electric locomotive units were purchased, originally, fifteen of which are being operated in freight service and two in the passenger service. These units are practically interchangeable with the exception of the gearing, the passenger locomotive being geared to operate normally at 40 or 50 mi. per hr. while the freight locomotives are geared to operate at from 15 to 25 mi. per hr., the maximum free running speed being approximately 35 mi. per hr. The continuous tractive

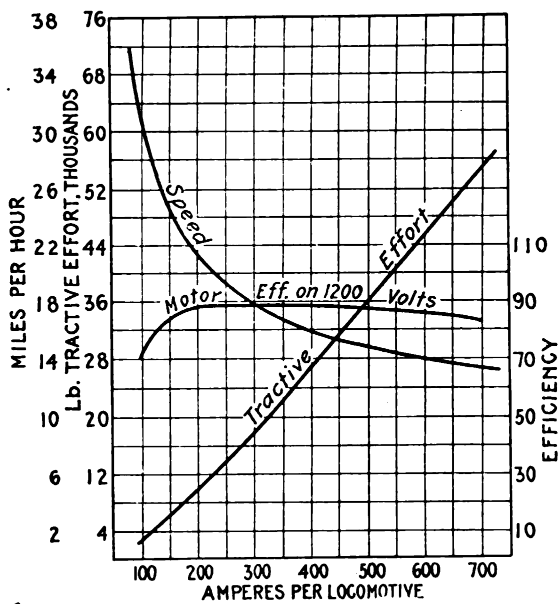


FIG. 12—CHARACTERISTIC CURVES OF FREIGHT LOCOMOTIVES

effort of the freight units is 25,000 lb., at 15 mi. per hr., but they are capable of exerting a maximum tractive effort of 48,000 lb. for five minute intervals, based on a coefficient of adhesion of 30 per cent.

All the locomotive units are of the articulated, double-truck type with twin gears mounted on projections provided on the wheel centers for the purpose, and in general mechanical design are similar to the electric locomotives in operation on the Great Northern railway, the Detroit River Tunnel railway and the Baltimore & Ohio railway. Each unit is equipped with four commutating pole motors wound to operate at 1200 volts each,

but insulated for 2400 volts, so that two are connected permanently in series and the four arranged in pairs, thus securing the usual two running points, with the difference that on the series position all four motors are in series, and in multiple the two pairs are connected in series parallel.

The standard rating of each motor is approximately 300 h.p., making the hourly rating of each locomotive unit about 1200 h.p. The control equipment is of the multiple-unit type and provides a total of 19 steps, ten of which are in series and nine in series parallel. The 2400-volt contactors, switches, fuses, etc., are located in enclosed compartments where they can be reached only by delibérate effort. The current for the operation of the control equipment, the air compressor, and the lights on the locomotive as well as the lights on the passenger coaches, is supplied by a 2400/600-volt dynamotor located in the main compartment of each locomotive unit.

A blower is direct-connected to the armature shaft of this dynamotor which provides artificial ventilation for the main motors and the rheostats. The principal data and dimensions pertaining to the electric locomotives are as follows:

Length inside of knuckles	37 ft. 4 in.
Length over cab	31 "
Height over cab	12 " 10 "
Height with trolley down	15 " 6 "
Width over-all	10 "
Total wheel base	26 "
Rigid wheel base	8 " 8 "
Track gage	4 " 8½ "
Total weight	160,000 lb.
Weight per axle	40,000 "
Wheels, steel tired	46 "
Journals	6 " 13 "
Gears, forged rims, freight locomotives	87 teeth.
Gears, forged rims, passenger locomotives	80 "
Pinions, forged, passenger locomotives	18 "
Pinions, forged, freight locomotives	25 "
Tractive effort at 30 per cent co-efficient	48,000 lb.
Tractive effort at one hour rating	30,000 "
Tractive effort at continuous rating	25,000 "

Work on the electrification began in the spring of 1912, and the first electric locomotive was run in Anaconda on May 14th, 1913, about a year later.

On May 27, two ore trains were hauled up Smelter Hill on trial trips with electric locomotives and on the following

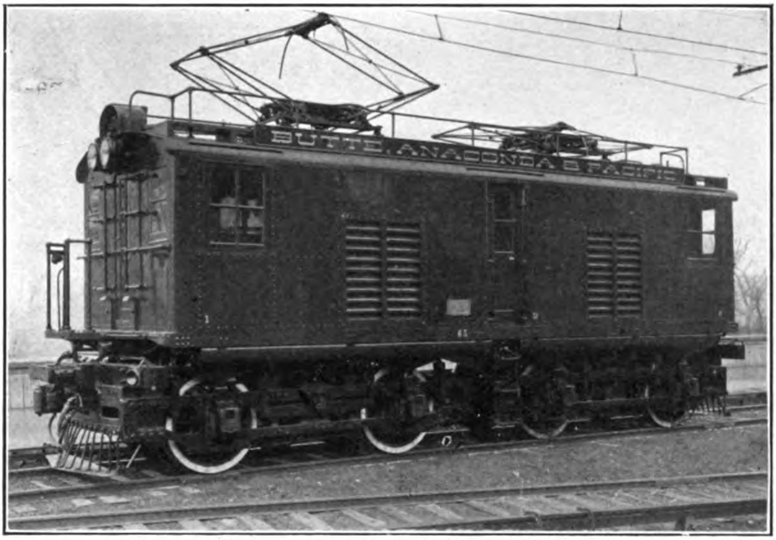


FIG. 9—EIGHTY-TON, 2400-VOLT LOCOMOTIVE [COX]

FIG. 10—TYPE OF STEAM SWITCHING LOCOMOTIVE FORMERLY USED ON BUTTE HILL [COX]

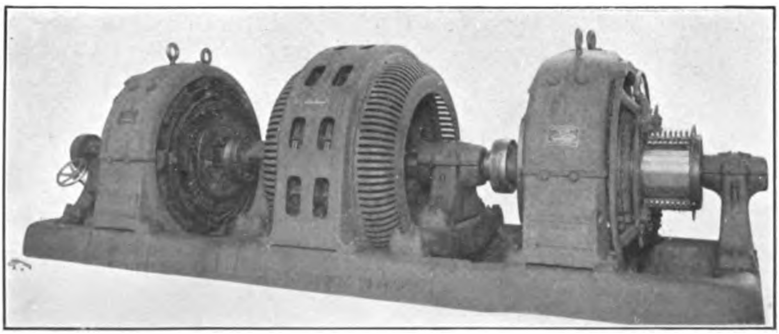


FIG. 11—2400-VOLT MOTOR-GENERATOR SET CONSISTING OF ONE 1450-KV.A., 2300-VOLT 60-CYCLE SYNCHRONOUS MOTOR AND TWO 500-KW., 1200-VOLT, D-C. GENERATORS IN SERIES.

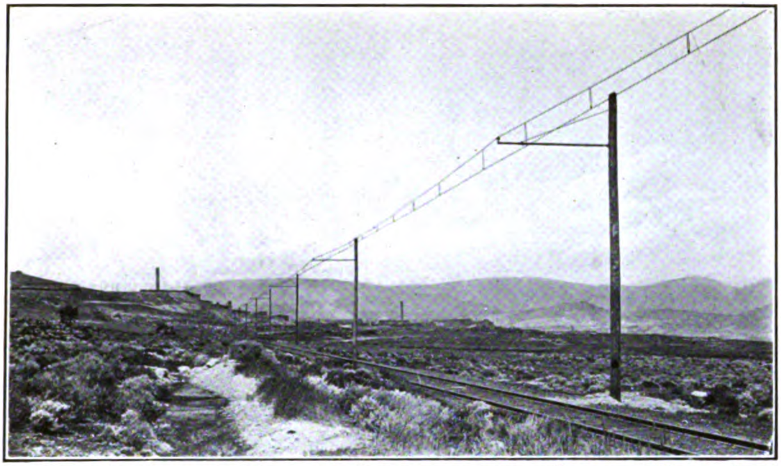


FIG. 13—BRACKET TANGENT CONSTRUCTION ON SMELTER HILL [COX]

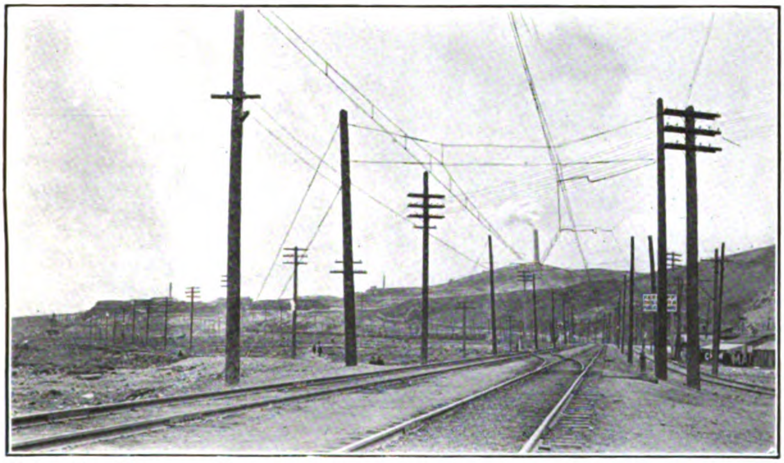


FIG. 14—DOUBLE TRACK SPAN CONSTRUCTION ON MAIN LINE AND GENERAL VIEW OF SMELTER HILL FROM WEST OF EAST ANACONDA YARDS.

FIG. 15—STORAGE BINS AT CONCENTRATOR [COX]

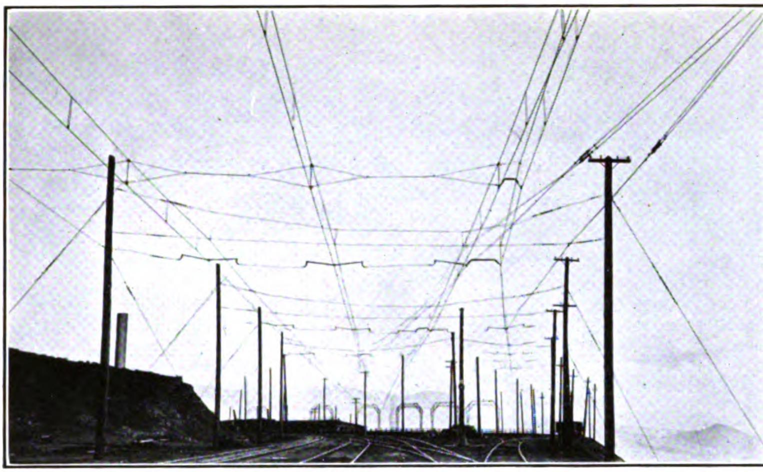


FIG. 16—CONCENTRATOR YARDS [COX]

FIG. 17—OVERHEAD CONSTRUCTION IN ROCKER YARDS [COX]

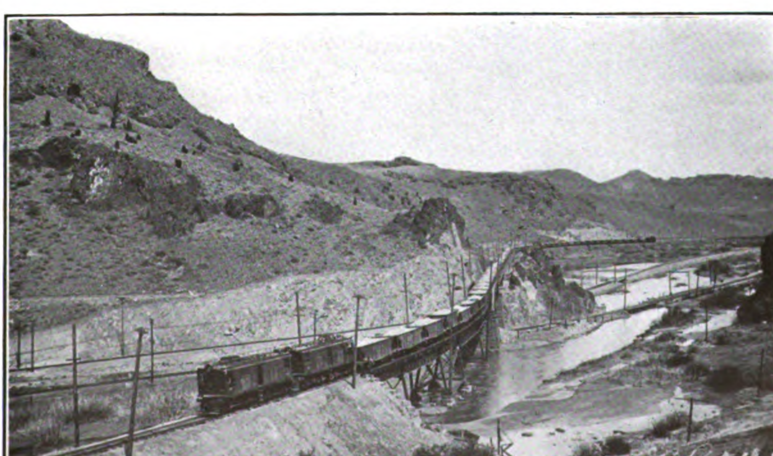


FIG. 18—SIXTY-FIVE CAR ORE TRAIN--TOTAL TRAILING LOAD 4550 TONS [COX]

day a double-unit electric locomotive took over the regular day service of hauling the ore from East Anaconda yards to the concentrator yards, the distance between which is approximately seven miles, the ruling gradient being 1.1 per cent compensated, and the grade fairly uniform through the entire distance, Fig. 6. The steam locomotives used in this service were of the Mastodon type, weighing 108 tons, 83 tons of which was on the drivers. The weight of the tender loaded was approximately 55 tons, making the total weight of locomotive and tender about 163 tons, which would average closely to the weight of the double-unit electric locomotive superseding it. The steam locomotive made ordinarily six round trips per shift, hauling 16 loaded ore cars per trip, equaling 96 cars per shift.

The average time for the trip from East Anaconda to the concentrator yards with 16 loaded cars for the steam locomotive was about 45 minutes. The double-unit electric locomotive began taking only 16 cars per trip but made 8 trips per shift, delivering 128 cars per shift. The average time for the up-hill trip with the electric locomotive was about 22 minutes or approximately half the time required by the steam locomotive for the same number of cars. Empty cars were taken to East Anaconda on the return trip which, being all down grade, gave the electric locomotive no decided advantage, as the speed in either case was limited to about 25 mi. per hr. for safety, on account of the curves in the line. The number of cars hauled per trip was kept the same with the electric locomotives in the beginning as it had been with steam, as it had been decided to make the change-over by gradually replacing one steam locomotive at a time with an electric, taking the engine crew off the one and placing it on the other, thus breaking them in on the electric locomotives in regular service.

One of the regular steam engineers had been given special instructions on the electric locomotives during the experimental running in order that he might become competent to act as instructor to the other engineers until they were sufficiently familiar with the electric locomotives to be left alone.

The load per trip in this service was gradually increased from 16 cars to 25 cars which is to be the standard for the present. The average time for the up-hill trip with 25 cars is about 26 minutes so that eight trips per shift is easily made, making a delivery of 200 cars possible or an increase of slightly more

than 108 per cent over what had been possible for the same crew with steam locomotives. These loaded ore cars average from 70 to 72 tons each, making the trailing load for a 25 car train from 1750 to 1800 tons.

On arrival at the concentrator yards the ore trains are taken by a switching engine called the "spotter", which places one car at a time over the weighing scales, after which they are re-arranged for placement over the concentrator bins from which the ore is fed by gravity to the crushers.

On June 20th this spotting service was taken over by a single-unit electric locomotive and on July 2nd the night service up Smelter Hill was taken over by the double-unit electric locomotive. The steam locomotive used for the spotting service was of the consolidation type and weighed 93 tons, 83 of which was on drivers, the tender weighing loaded 62 tons making the total weight of engine and tender 155 tons. The steam locomotive used in the night service on Smelter Hill was similar to that used in the day service. When the electric engines were put on the night service all the handling of ore between East Anaconda and the concentrators was done electrically, and the hauling capacity per crew was so much greater that it was no longer necessary to have a "spotter" crew on the night shift so that this crew was eliminated, and the night crew hauling the ore up Smelter Hill did their own spotting on arrival at the concentrator yards, it being no longer necessary to make the regular number of trips. Thus where formerly during steam operation four engine and train crews had been required, now with electric locomotives three similar crews were able to do the same work and in less time, thereby reducing the number of crews required in this particular service 25 per cent.

On July 9th the stock bin engine was replaced by an electric unit. This engine is engaged mostly in a switching service placing cars of coke, coal and other supplies at the smelter. The type of steam engine used here was the same as that used for the "spotter" service described above.

Another engine locally known as the "tramp" because of the irregularity of the time or place of its service was partially replaced on July 24th. As some of the tracks over which this engine had to operate at times had not been equipped with overhead wires, the infrequency of their use not warranting the expense when other conditions made it necessary to keep one or more steam locomotives in operation, the service of this

electric unit was intermittent. This practically completed the electrification of the Smelter Hill service and no further extension of electrical operation was made until October as the trolley construction on the main line was not completed until that date.

On the forenoon of Sept. 30th an inspection trip was made over the main line from Anaconda to Butte and in the afternoon a special train carrying officials and visitors from a neighboring road was taken from Butte to Anaconda and return by one of the electric locomotives intended for the passenger service. On October 1st the regular passenger service between Butte and Anaconda was taken over for electrical operation. The steam locomotives used in the passenger service weigh approximately 80 tons, 60 tons of which were on drivers, the tender loaded weighing 52 tons, making the total weight of engine and tender 132 tons. The distance between the stations—Anaconda to Butte—is 25.7 miles, the schedule time for the trip, one hour. No change has been made in this time though a reduction of 20 per cent would be possible with the electric locomotives were such desired. The standard passenger train consists of one mail and baggage coach and two to four passenger coaches, but as many as 12 passenger coaches are handled by a single electric unit on special occasions, such as excursions and on holidays.

The baggage coaches average approximately 40 tons in weight and the passenger coaches 45 tons, each making the gross weight of the three-car electric train approximately 210 tons, whereas that of a similar steam train was 262 tons, showing a reduction of 19 per cent in favor of the electric locomotives with approximately 33 per cent more weight on its drivers. As had been done in the freight service, the steam enginemen in the passenger service were transferred from the steam to the electric locomotives with but little previous instructions, and after the first day or so were left mostly to themselves. It may be of interest to note here that on the day shift, averaging four trips per day, during the first five months the passenger train did not come in late a single time on account of engine trouble. A comparison of the delays to the passenger trains for the month of June, 1913, steam operation, with the same month, electrical operation, 1914, as shown in Table No. 5, results as follows:

	No. of Trains	Delays on Account of				Total Delays
		Meeting Points	Power	Engine Failure	Lost Run Time	All Causes
		Hr. Min.	Hr. Min.	Hr. Min.	Hr. Min.	Hr. Min.
Steam, 1913	272	15 : 49		44	4 : 13	20 : 46
Elec., 1914	280	3 : 54	27	24	25	5 : 10
Decrease	8*	11 : 55	27*	20	3 : 48	15 : 36
Percentage of saving due to electrical operation	2.94*	75·66		45·45	90·10	75·12

* Increase.

June was taken at random for a comparison, as that month's records were still in the office file but the results are considered representative of general performances.

On October 10th a double-unit electric locomotive was put in the day freight service on the main line between East Anaconda and Rocker, a distance of 20.1 miles. The steam locomotive replaced in this instance was of the Mastodon type weighing 103 tons, 77 tons of which was on drivers, the tender loaded weighing 55 tons, making the total weight of locomotive with tender 158 tons. The standard train hauled on the trip west was 50 to 55 loaded ore cars weighing approximately 3500 to 4000 tons gross and the average running time of such trains where no stops were made was about 1½ hours, corresponding to an average speed of approximately 13.4 miles per hour. In the beginning the electric locomotive took only the standard train but made the trip without stop in about one hour, corresponding to an average speed of 20 mi. per hr. The ruling gradient on the westward trip is 0.3 per cent and about half the distance is down grade. On the 0.3 per cent grade with a 55-car train, the steam locomotive made about seven mi. per hr. The electric locomotives with similar train now make about 16 mi. per hr. on the same grade.

The weight of the trains hauled by the electric locomotives on this run has been gradually increased up to 65 loaded ore cars averaging about 71 tons each, making the gross weight

trailing about 4620 tons. Adding 160 tons for the weight of the double-unit electric locomotives and 20 tons for the caboose makes a gross train weight of approximately 4800 tons.

The remainder of this main line freight service was gradually taken on during the months of October and November, thus completing the electrification of the main line service. As many as 76 ordinary freight cars loaded with coal, coke and general merchandise have been taken in a single train on the west-bound trip and 85 empties are frequently taken from East Anaconda to Rocker east-bound, the ruling grade being 1 per cent.

Table 4 gives comparative results of the month of June 1913 steam operation vs. the same month, 1914, electrical operation of this main line service, showing that with a slight increase in the total tons of ore hauled the average tons per train was increased from 1761 to 2378 or 35 per cent, thus decreasing the average number of trains per day from 12.5 to 9.3, or 25.6 per cent.

Table No. 3, giving a comparison of the time per trip for these trains, is representative of the gain in this direction to be added to the decrease in the number of trains. The average time per trip during steam operation was approximately two hours and 25 minutes, while with the electric locomotive it was approximately one hour and 45 minutes, showing a decrease of 40 minutes, or 27.5 per cent. These figures represent the time put in by the crews between Rocker and Anaconda, the distance being 21.8 miles.

The result of these improvements is indicated in Tables 1 and 2, which show that the overtime in this particular service has been decreased 73.5 per cent and the total time 42 per cent, resulting not only in greater economy to the railway company but in shorter and easier hours for the crews.

The service on the Missoula Gulch line running between Rocker and Butte Hill yards was taken over for electrical operation on October 20th. This line is 4.5 miles in length and the ruling gradient 2.5 per cent, Fig. 5. The steam locomotives used on this line were of the Mastodon type, weight 106 tons, 87 tons of which were on the drivers, the tender loaded weighing 56 tons, thus making the total weight of engine and tender 162 tons. Two complete crews had been required to handle this service during steam operation, averaging six trips per day each. A single crew with a double-unit electric locomotive has

been doing this work successfully. Thirty-five to 45 loaded ore cars are taken down from Butte Hill yard to Rocker, and about an equal number of empties taken up. In addition to the empties, large quantities of timber and supplies for the mines are delivered over this line.

TABLE I

NUMBER OF HOURS ENGINE CREWS WERE EMPLOYED IN VARIOUS SERVICES—JUNE 1913 STEAM OPERATION

	Anaconda Yard		Butte Hill Yard		Local		Road	
Date	Regular Time Hr.	Over Time Hr.	Regular Time Hr.	Over Time Hr.	Regular Time Hr.	Over Time Hr.	Regular Time Hr.	Over Time Hr.
June 1	80	14	20	4.50	20	3.25	30	13.75
2	90	6.50	20	6.50	20	5.75	40	17.25
3	50	5	—	—	20	5.25	40	15
4	70	11.75	20	8.25	20	6.75	30	11.50
5	80	11.75	20	8.00	20	6.00	30	12.25
6	70	9.25	20	9.00	20	10.00	30	14.50
7	80	13.75	20	8.75	20	6.50	30	11.25
8	70	8.00	20	8.75	20	4.75	30	12.25
9	70	10.50	20	11.50	20	8.25	30	11.50
10	80	8.75	20	7.75	20	2.00	30	9.00
11	80	13.	20	10.25	20	7.00	30	10.50
12	70	7.00	20	2.00	20	5.25	30	12.00
13	40	5.25			10	1.00	20	6.75
14	70	12.25	20	11.25	20	7.50	30	9.50
15	70	10.25	20	8.75	20	5.25	30	11.00
16	80	8.75	20	9.75	20	16.00	30	9.25
17	80	7.75	20	9.00	30	11.00	30	15.25
18	70	12.25	20	7.50	20	10.75	30	12.50
19	70	9.50	20	9.00	20	3.75	30	8.00
20	80	12.00	30	10.75	20	5.75	30	8.75
21	80	9.75	20	10.25	20	3.50	30	12.75
22	70	5.50	20	7.75	20	5.75	30	10.00
23	70	7.00	20	8.25	20	6.75	30	8.75
24	80	7.50	20	4.50	20	8.00	30	9.00
25	70	9.25	20	6.00	20	9.00	30	11.50
26	80	10.25	20	9.00	20	7.00	30	13.27
27	70	7.75	20	7.50	20	7.00	30	10.25
28	70	5.50	20	2.50	20	4.75	30	9.00
29	80	6.00	20	1.50	20	3.75	30	9.75
30	80	8.75	20		20	7.00	30	9.50
Total	2200	274.50	570	208.50	600	194.25	910	335.50

Tons Ore Hauled During Month—311,450.

On November 25th, the last of the electric locomotive units went into service, thus completing the electrification originally intended. The full electrical service has, therefore, now been in operation more than nine months and that on Smelter Hill

more than 15 months so that the total locomotive miles operated would be approximately close to an average year's performance.

TABLE II.

NUMBER OF HOURS ENGINE CREWS WERE EMPLOYED IN VARIOUS SERVICES—JUNE 1914 ELECTRICAL OPERATION

	Anaconda Yard		Butte Hill Yard		Local		Road	
Date	Regular Time	Over Time	Regular Time	Over Time	Regular Time	Over Time	Regular Time	Over Time
June 1	70	7.25	20	1.25	20	2.50	30	2.25
2	70	8.25	20	4.00	20	2.50	30	5.00
3	70	9.50	10	1.00	20	4.00	30	1.25
4	60	7.25	10	2.00	20	2.75	30	4.25
5	60	12.50	10	2.00	20	2.75	20	2.50
6	60	7.25	10	2.00	20	2.50	20	2.25
7	70	8.25	10	2.00	20	2.00	20	6.25
8	60	8.75	10	1.75	20	2.75	20	3.00
9	60	10.50	10	1.50	20	4.75	20	4.75
10	60	11.25	10	1.75	10	1.00	20	1.75
11	60	5.00	10	1.50	20	3.75	20	1.25
12	60	9.00	10	1.00	20	2.00	20	1.25
13	30	1.75	10	1.00	10	1.00	10	4.00
14	60	5.50	10	1.25	20	2.25	20	1.25
15	60	6.50	10	1.00	20	2.75	20	1.50
16	60	4.00	10	1.50	20	2.50	20	2.00
17	60	7.75	10	1.00	20	3.00	20	2.75
18	60	8.75	10	1.75	20	2.25	20	1.50
19	60	7.25	10	3.00	20	2.25	20	2.25
20	60	10.75	10	1.75	20	2.25	20	5.75
21	60	8.75	10	1.75	20	2.25	20	1.25
22	50	5.50	10	1.00	20	2.75	20	2.25
23	60	6.75	10	1.00	10	1.50	20	3.50
24	60	11.25	10	1.50	20	3.00	20	3.50
25	60	7.75	10	1.50	20	2.25	20	5.25
26	60	5.75	10	1.25	20	2.50	20	1.75
27	60	8.50	10	1.25	20	2.00	20	3.75
28	60	4.25	10	3.00	10	1.75	20	2.00
29	60	6.00	10	1.00	10	1.75	20	5.50
30	60	10.50	10	1.25	20	2.25	20	3.50
Total	1800	232.00	320	48.50	550	73.50	630	89.00
Decrease	400	42.50	250	160.00	50	120.75	280	246.50

	Regular	Over	Total
Total time 1913—Steam	4280.00	1012.75	5292.75
" " 1914 Electric	3300.00	443.00	3743.00
Decrease	980.00	569.75	1549.75
Percentage of Decrease	22.89%	56.26%	29.28%

Tons ore hauled during month—319,700

This was the first installation of 2400-volt direct-current apparatus for the operation of a railway in this country, 1500 volts being the highest heretofore installed for such a purpose.

The results have been more satisfactory than had been anticipated and the development charges due to such imperfections as usually appear during the first year of operation have been perhaps smaller than is customary with an undertaking of like magnitude, even where standard apparatus is used.

TABLE III.

COMPARISON OF TIME REQUIRED PER TRIP OF FREIGHT TRAINS.
BETWEEN ROCKER AND ANACONDA—FIRST 2 DAYS OF JUNE 1913, STEAM OPERATION WITH CORRESPONDING 3 DAYS ELECTRICAL OPERATION.

		1913 Steam				1914 Electric			
East Bound.				West Bound		East Bound		West Bound	
Train	No.	Tons	Time	Tons	Time	Tons	Time	Tons	Time
			Hr. Min.		Hr. Min.		Hr. Min.		Hr. Min.
	1	255	1 : 13	1705	2 : 00	380	1 : 02	2915	2 : 00
	2	1010	1 : 50	2848	2 : 05	314	1 : 15	3092	2 : 00
	3	1010	3 : 20	3760	2 : 10	1336	1 : 45	4088	1 : 20
1st	4	915	2 : 40	3420	2 : 30	1260	1 : 40	3830	1 : 10
	5	1047	2 : 30	2944	3 : 45	1240	1 : 40	4009	2 : 05
	6	1000	2 : 20	2935	2 : 05	..	..	..	..
	7	1010	4 : 00	..	..	..	..	..	..
	1	415	1 : 07	3110	3 : 40	416	1 : 10	3100	2 : 00
	2	1010	2 : 10	3760	2 : 10	1154	1 : 40	3220	1 : 25
2nd	3	1010	2 : 45	2884	2 : 00	1298	2 : 00	3752	2 : 20
	4	1010	3 : 00	3420	2 : 00	458	1 : 45	4029	2 : 10
	5	1104	2 : 20	3420	2 : 00	1232	2 : 00	3720	2 : 20
	6	1000	3 : 00	2910	2 : 50	1190	1 : 55	2840	2 : 35
	1	380	1 : 02	3380	2 · 50	470	1 : 03	2515	1 : 15
	2	1010	1 : 50	1630	2 : 45	1280	1 : 40	3964	1 : 10
3rd	3	992	2 : 50	200	2 : 00	1298	2 : 05	4098	1 : 30
	4	884	2 : 20	0	1 : 20	482	1 : 40	3760	1 : 40
	5	1046	2 : 40	3150	2 : 30	1074	2 : 10	3138	2 : 30
	6	1084	3 : 15	2770	2 : 40	1200	2 : 15	0	1 : 10
Totals	19	17192	46 : 12	18-48246	43 : 20	17-16082	28 : 45	17-56070	30 : 40
Av'ge per Train.....		905	2 : 26	2680	2 : 24	946	1 : 41	3298	1 : 48

Grand Average. 1768 tons per train, time per trip 2 25, 2150 tons per train, time per trip 1:45.

Result. 20.0% increase in tonnage per train, 27.58% decrease in time per trip.

*On June 5th, 1914 one main line crew was taken off and the tonnage of the remaining trains increased so as to handle the regular business.

Difficulties especially attributable to the higher potential have been negligible, and while there have been occasional instances of arcing and flashing or short circuits due to ordinary causes, the resultant damages have been really smaller than

might be expected from a like occurrence on a 600-volt installation of equal capacity.

The original brushes supplied in the motors chipped badly

TABLE IV.

COMPARISON OF FREIGHT TRAIN MOVEMENTS BETWEEN ROCKER AND ANACONDA. STEAM OPERATION FOR MONTH OF JUNE 1913 WITH ELECTRICAL OPERATION FOR SAME MONTH 1914

	1913 Steam				1914 Electric			
	East Bound		West Bound		East Bound		West Bound	
Date	No. Trains	Total Tons	No. Trains	Total Tons	No. Trains	Total Tons	No. Trains	Total Tons
1	7	6247	6	17612	5	4530	5	17934
2	6	5549	6	19504	6	5748	6	20661
3	6	5396	6	11130	6	5804	6	17425
4	7	5584	6	14632	6	6127	6	18332
5	7	5848	6	14625	5	5334	5	17155
6	7	5877	6	19471	4	4804	4	17563
7	7	5698	6	21021	5	6579	5	19073
8	7	6388	7	17023	5	6083	5	14170
9	6	5508	7	12507	5	5796	4	15292
10	6	5039	6	19240	5	6027	5	16926
11	6	5381	5	15925	4	5345	4	12832
12	5	4376	6	18112	5	5670	5	17881
13	5	3705	5	9565	2	2322	1	3042
14	6	4912	6	7841	4	4638	4	13803
15	7	5652	7	17691	5	5262	4	15761
16	6	5180	7	17518	4	5116	4	16408
17	6	5475	6	16090	5	6433	5	20581
18	6	5483	6	16592	4	5141	4	17546
19	7	6003	6	18301	5	6661	5	18489
20	7	5277	6	22283	5	6768	5	17992
21	7	5737	6	18986	4	5120	4	11932
22	7	5082	6	15464	5	6017	5	15613
23	6	5386	6	11941	4	4121	4	15930
24	6	5098	6	18210	5	6556	5	18917
25	7	5544	7	17992	5	6531	5	16855
26	7	5690	6	18304	5	6782	5	18593
27	7	5935	6	14764	4	4362	4	18038
28	7	5754	5	17297	4	5047	4	14884
29	6	5105	6	19899	5	6455	5	17941
30	6	5221	6	17584	5	6617	5	18128
Total.......	193	163,130	182	497,124	141	167,796	138	495,697
Average....	6.4	845	6.1	2,731	4.7	1 [illegible]	4.6	3,592

Grand Average 12.5 trai[illegible]r day, 1761 tons per train. 9.3 trains [illegible]er day, 2378 tons per train.

Results—25.6% les[illegible]s. 35.0% greater tonnage per train.

and before all these had been replaced it was often found when the units were brought in for regular inspection that some of the brushes were broken entirely into pieces, and while there

was evidence that a flash-over might have occurred at some time, no harm had resulted other than the blowing of the motor fuse, on the replacement of which the engine was continued in service until its regular time for inspection, when the cause of the fuse blowing would first be discovered.

The fact that the locomotives continued in service thus is sufficient evidence of the harmlessness of the arc-over and in no instance of the kind has any real damage been done. The locomotives have made from 25,000 to 50,000 miles each and without exception the motors are in excellent condition. The wear on the commutators is imperceptible and the general performance of the entire equipment is quite as satisfactory and promising as that of any railway equipment with which we have had experience in similar service.

The overhead construction has been quite satisfactory and a recent examination of the trolley wire shows no indication of unusual wear. The roller pantographs are operating quite successfully, the average life of these being from 10,000 to 12,000 miles per roller. Where a double-unit locomotive is operated, the two pantographs are connected electrically by a main bus line, and the average current collected by each, when ascending the grades with standard loads, is from 350 to 400 amperes. Two pantographs operating in multiple thus will collect more than double the current that can be successfully collected by a single pantograph for the reason that sparking is usually due to the momentary breaking of contact between the trolley wire and the roller caused by hard spots in the line. When two pantographs are operated in multiple both do not encounter these hard spots at the same instant, hence one of the two is more apt always to be making good contact, so that the flow of current is not so frequently interrupted and consequently the sparking is greatly reduced. The double units operating on Smelter Hill were run experimentally for several days with only a single roller making contact with the wire, the operation being quite successful with the single roller collecting an average of 650 to 750 amperes while running at 16 to 17 mi. per hr. and 800 to 1000 amperes during the accelerating period in multiple. The sparking was not serious except at hard points in the line and with two rollers in multiple there should be no difficulty in collecting 500 to 600 amperes per roller, which at 2400 volts should be equal to the requirements of any ordinary locomotive unit.

The bearings first used in the rollers were provided with ordinary bushings lubricated with oil but when the bushings became slightly worn the oil was thrown out along the spindle and had to be replenished at comparatively frequent intervals. This was not serious in the operation of the freight locomotives but became more so when the passenger service was started, as the higher speed caused the oil to be thrown out more quickly, resulting in very short life of the bushings. Slight changes were made in the bearings and grease was substituted for the oil as a lubricant, which proved quite satisfactory. However, the vibration which results from too much play in the bearings of the roller when operating at high speeds made it desirable to increase the life of these bearings as much as possible, so that, later, roller bearings with grease lubrication were installed with excellent results. As yet, these have not been in operation a sufficient length of time to indicate definitely how long they may be expected to last, but it would appear that the bearing will last much longer than the roller and that the attention required for the adjustment and lubrication of the bearing or the roller will be negligible.

On account of a decision of the mining company to divert to the Washoe smelter, at Anaconda, the shipment of approximately 3000 tons of ore per day that had previously been sent to the smelter at Great Falls, which will increase the ore traffic over the Butte, Anaconda & Pacific approximately 25 per cent, an extra motor-generator set, a duplicate of the original sets, has been installed in the Anaconda substation as a spare set, and four additional electric locomotive units were ordered and will be delivered within the next three months. These units will be duplicates of the original ones except that they are to be arranged for operating with an extra tractor truck attached when desired. This tractor truck will be a duplicate of the standard truck used under the regular units, with two standard motors mounted upon it with the necessary arrangements for coupling, both mechanically and electrically, so that the standard unit and the tractor truck may be operated as a single unit. The motors of the tractor truck are connected with those on the standard unit in such a manner as to place all six motors in series on the series points of the controller, and with a series multiple connection with three motors in each series, on the multiple position of the controller. This arrangement will make the tractive effort of the new unit 50 per cent greater

that that of a standard unit for the same input, with a reduction in the free running speed of about $33\frac{1}{3}$ per cent.

This arrangement was made advisable because of the increase in the weight of the trains taken up Smelter Hill, amounting to approximately 56 per cent. A single unit when used in the "spotting" service is taxed close to the slipping point of its wheels when accelerating these heavier trains on the 0.5 per cent grades under ordinary conditions of weather, and has to be handled very carefully with the continuous use of sand when the condition of the rails is unfavorable. Connecting the additional motors in series will also result in considerable power economy, since with a single unit the controller is seldom off the series resistance points, on account of the heavy trains handled and the short movements required.

Small change in the personnel of the maintenance or operating departments of the railway has been made on account of the electrification, nor has there been any reduction in salaries or wages. An extra man with electrical experience was placed in the shops to supervise the electrical repairs to the locomotives and three linemen were retained for the maintenance of the trolley system.

The three steam switching locomotives used for concentrating the ore at and distributing supplies from Butte Hill yards are continued in this work for reasons heretofore stated. Another steam locomotive is used on the Georgetown branch and a fifth one operates at intervals over unelectrified tracks at the Anaconda end. Approximately 20 per cent of the total locomotive-miles now being operated is by these five steam locomotives, the cost of which, as shown in Table 6, is upwards of 40 per cent of the total cost of all locomotive performance.

The electrification of the remaining tracks on Butte Hill has been recommended and no doubt will be commenced at an early date. Table 6 referred to was made up from the regular monthly locomotive performance sheets of the railway company, from which the principal saving resulting from the electrification may be noted. The saving from the partial substitution of electric power for coal is the chief item, being at the rate of $150,727.04 per year, which is remarkable when it is considered that more than 39 per cent of the total combined costs for fuel and power for the period considered was for coal and charged against electrical operation. In this instance the saving on this item alone would undoubtedly justify the

[illegible]	1914	10	55			55	8	1:42	52				8:10	8:33
	1913	8	02			02	15	15:00	3:20				14:30	14:39
[illegible]	1914	10	30			30	10	10:30	30	42			11:42	15:12
	1913	8	34			38	15	10:52	3:40			02	13:10	13:44
[illegible]	1914	8	12			12	16	10:02					10:02	10:50
	1913	8	10			10	10	8:32	1:12			04	8:24	10:04
[illegible]	1914	8					8	1:22					1:22	1:22
	1913	8	31			31	15	15:00	1:20			16	16:00	16:49
[illegible]	1914	8	11			11	10	8:20	10	30			10:30	10:31
	1913	8	1:40			1:40	15	15:21	4:10	3:30		04	18:32	31:12
[illegible]	1914	8					8	1:20	10				8:00	8:03
	1913	8	02		11	16	15	11:32	3:50	1:00		16	12:53	12:48
[illegible]	1914	8					8	9:22					9:22	9:22
	1913	14	31		4	41	13	10:21	3:50	40	20	04	12:21	10:23
[illegible]	1914	10					8	1:40	10				1:20	1:20
	1913	8					15	15:40	3:44			32	10:03	10:02
[illegible]	1914	55			6	08	4	3:32					3:32	3:44
	1913	15	52		34	1:05	10	11:00	3:42		1:22	14	12:44	10:49
[illegible]	1914	8	03			08	10	10:40	10				10:20	10:48
	1913	8	40		15	1:01	15	10:20	8:21			12	16:20	30:41
[illegible]	1914	8					8	8:00	10				8:10	8:10
	1913	8	40		9	30	10	15:20	2:50	1:32		02	16:20	30:30
[illegible]	1914	8					10	13:22	30	1:12			12:40	12:40
	1913	8	55			55	15	10:30	3:32			51	14:50	14:49
[illegible]	1914	54	42	12	11	1:11	8	10:50	30	10			10:20	15:01
	1913	8	54		8	35	15	15:12	3:02		1:12	10	12:42	19:14
[illegible]	1914						15	10:42	42	30			15:00	15:00
	1913	12	32		31	1:12	13	15:38	2:50			40	18:38	18:21

TABLE V

DELAYS TO TRAFFIC COMPARING THE MONTH OF JUNE 1913 STEAM OPERATION WITH JUNE 1914 ELECTRICAL OPERATION

June	Passenger Service.						Freight Service.								
	No. of Trains	Delay for Meeting Points	Delay for Power	Delay Acct engine Failures	Lost Running Time	Total Delays	No. of Train	Terminal Delays and Switching	Delay for Power	Delay for Meeting Points	Delay due to derailments and break-in-twos	Delay Account Eng. Failures	Delay Water and Coal	Total Delays	Grand Total Delays
		Hr. Min.	Hr. Min.	Hr. Min.	Hr. Min.	Hr. Min.		Hr. Min.	Hr. Min.	Hr. Min.	Hr. Min.	Hr. Min.	Hr. Min.	Hr. Min.	Hr. Min.
1st, 1913	14	43			18	1 : 1	14	12 : 15		4 : 55	30			17 : 40	18 : 41
1914	8						12	10 : 5		1 : 20	30			11 : 55	11 : 56
2nd 1913	8	42			2	44	8	12 : 5		2			35	14 : 40	15 : 24
1914	4	5	17			22	12	11 : 10	3 : 20	30				15	15 : 22
3rd 1913	8	15		14	5	34	12	9 : 30		4 : 30			10	14 : 10	14 : 44
1914	4						12	10 : 30		45		30		11 : 45	11 : 45
4th 1913	8	10				10	12	11 : 28		3 : 50			19	15 : 37	15 : 47
1914	8	5				5	10	11 : 00		10		45		11 : 55	12 : 00
5th 1913	8	17			5	22	12	14 : 00		4 : 45			40	19 : 25	19 : 47
1914	4	40				40	10	11 : 35		35				12 : 10	12 : 50
6th 1913	4	1 : 10			3	1 : 13	14	13 : 25		3 : 10	1 : 05	24	40	18 : 44	19 : 57
1914	4						8	7 : 37		10				7 : 47	7 : 47
7th 1913	13	07			51	58		11 : 20		6 : 30			40	18 : 30	19 : 28
1914	10	05			05	10	10	7 : 00		20		55		8 : 15	8 : 25

EXPENDITURES IN DETAIL AND PERFORMANCE OF LOCOMOTIVES—COMPARING SIX M

Month	Locomotive Miles: Freight	Passenger	Switching	Non Revenue and Special	TOTAL	Maintenance: Repairs	Depreciation
December 1912 steam	23647	7041	27307	2152	60137	$ 9216 24	$ 1381
January 1913 steam	26018	6976	29601	4228	65803	8191 12	1340
February 1913 steam	23514	6908	25041	4700	59863	9080 59	1340
March 1913 steam	24948	7224	28136	6207	66515	8418 03	1340
April 1913 steam	29649	8482	21747	7802	60030	8844 76	1340
May 1913 steam	27167	7811	22667	10863	68080	6582 33	1340
TOTAL 6 MONTHS STEAM	148943	42185	153499	35454	380381	$51,102 97	$ 8082
Cost per locomotive mile cents						13.45	2
Cost per ton mile—cents						0.0044	0.0
December 1913, steam	3000	36	9880	6940	19855	$ 5767 97	$ 709
electric	35152	7290	16140	352	59260	1459 63	
Total	38152	7326	25820	7298	78045	$ 7027 60	$ 709
January, 1914 steam	3161		9212	2440	11522	$ 3577 93	$ 591
electric	30889	7264	15590	333	59860	1659 65	
Total	38050	7264	24822	2782	74718	$ 5237 58	$ 591
February, 1914 steam	3152		9068	1576	13790	$ 1638 43	$ 591
electric	32384	6008	15985	327	56304	2798 81	338
Total	35536	6008	25053	1903	70100	$ 4437 24	$ 930
March, 1914 steam	3012		8584	2151	13747	$ 2035 95	$ 591
electric	34664	7336	14279	363	56642	3064 40	2711
Total	37676	7336	22863	2514	70389	$ 5100 35	$ 3302
April, 1914, steam	2415	345	8001	2175	12929	$ 1441 39	$ 591
electric	34098	7024	12883	768	54773	3076 05	2711
Total	36513	7372	20884	2943	67712	$ 4517 00	$ 3303
May, 1914 steam	1569	16	8185	920	10690	$ 1017 37	$ 591
electric	36087	7658	13931	107	57783	3763 93	2711
Total	37656	7674	22116	1027	68773	4781 30	$ 3303
Total 6 Months—							
STEAM	16309	420	53093	16217	86090	$15290 04	$ 3729
ELECTRIC	210404	43170	88804	2250	344628	$15822 47	8471
TOTAL	226713	43590	141867	18467	430637	$31121 51	$12201
Costs per locomotive mile, steam—cents						17.78	4
Cost per locomotive mile, electric—cents						4.59	2
Average costs per locomotive mile, combined steam and electric—cents						7.23	2
Average costs per ton mile, combined steam and electric—cents						0.0360	0.0
Decrease shown in favor of electrical operations	77770*	1105*	11632	16987	50256*	$20041 46	$ 4118
Savings resulting per year on the above basis—decreased operating expenses						$40082 92	$ 8236
Percentage of saving account of electrical operation decreased operating expenses						39.17	50

*Increase.

OPERATING EXP—DEC. 1913 TO MAY, 1914.

		rage for 6-months period.	
		1912	1911
Maintenance of way a	57	$81284.00	$62028.28
Maintenance of equip	3	$109495.65	$103796.27
Traffic expenses,.....	2	$ 4371.95	$ 3727.60
Transportation expen	4	$259948.95	$241571.49
General expenses.....	5	$ 17646.52	$ 13874.55
Total Operating Expe	1	$472747.07	$424998.19
Net operating revenue	0	$103692.27	$111106.97
Taxes...............	9	$ 12881.99	$ 12306.88
Operating income....	2	$ 90810.28	$ 98210.09

† Increase
* Decrease

[J. B. COX]

Operating Expenses Comparison of Six Months Steam Operation—Dec. 1912

		December	January	February
Maintenance of way and structure	1913	$11233 82	$13252 96	$10885 20
	1914	14377 32	10107 61	9607 83
	Decrease	$ 3143 50*	$ 3145 35	$ 1277 37
Maintenance of equipment	1913	$20824 74	$24012 20	$26219 97
	1914	22765 83	18472 16	17281 41
	Decrease	$ 1941 09*	$ 5540 04	$ 8938 56
Traffic expenses	1913	$ 760 84	$ 877 49	$ 640 02
	1914	703 55	613 98	548 86
	Decrease	$ 57 29	$ 263 51	$ 91 16
Transportation expenses	1913	$56171 03	$54864 94	$57077 42
	1914	47772 32	44243 99	41529 43
	Decrease	$ 8398 71	$10620 95	$15547 99
General expenses	1913	$ 3218 70	$ 2462 68	$ 2021 97
	1914	2963 73	3185 52	4148 42
	Decrease	$ 254 97	$ 722 84*	$ 2126 45*
Total Operating Expenses	1913	$92209 13	$104470 27	$96741 58
	1914	88582 75	76623 26	73912 95
	Decrease	$ 3626 38	$ 27847 01	$22828 63
Net operating revenue	1913	$18075 01	$ 4518 47	$ 7121 88
	1914	43271 31	54232 62	48926 12
	Increase	$25196 30	$ 49714 15	$41804 24
Taxes	1913	$ 2638 58	$ 2000 00	$ 2000 00
	1914	3205 50	2500 00	2500 00
	Increase	$ 566 92	$ 500 00	$ 500 00
Operating income	1913	$15436 43	$ 2518 47	$ 5121 88
	1914	40065 81	51732 62	46426 12
	Increase	$24629 38	$ 49214 15	$41304 24

† Increase
* Decrease

expenditure covering the entire cost of electrification. It is to be noted that with a single exception, that for depreciation of equipment, every item of expenditure in the locomotive performance sheet shows a substantial percentage of decrease in favor of electrical operation.

It is the practise of the railway company to adjust depreciation charges on all locomotives at the beginning of each half year. The amount to be charged to the depreciation of a new locomotive for the first half year it is in service is determined by taking a fixed percentage of its cost to the company, one-sixth of this amount being charged against the locomotive each month for the half year, at the end of which the amount of the depreciation for the period is deducted from the original cost of the locomotive to give a new value, of which the original fixed rate of percentage is taken in determining the amount of the depreciation for the following half year, and so on.

The Interstate Commerce Commission ruling does not permit a depreciation charge until the locomotive actually becomes the property of the railway company and as the electric locomotives were not formally taken over by the company until March, 1914, the proper monthly charge begins only with that month in the regular monthly performance sheet from which Table 6 was complied. In fairness to the performance sheet, only the proper monthly depreciation charges were made, but as some of the locomotives had been in service eight months before these charges began, an adjustment was necessary to make a proper distribution of the back depreciation, so that while Table 6 shows only the proper monthly charge for the six months compared, amounting to $8,471.84, in Table No. 7 under "maintenance of equipment" the total back charges were included, amounting to $20,047.48. It is evident that the depreciation reckoned on this basis for the first months of service would be comparatively high.

The total saving from locomotive performance alone as indicated by Table 6 is at the rate of $237,581.82 per year, to which should be added the credit of handling an increase of traffic at the rate of 13,938,136 ton-miles per year or 8.77 per cent more than was handled by the steam locomotives during the period compared. To this saving from locomotive performance should be added the saving from trainmen's wages, which is at the rate of $31,146.30 per year, or a decrease of approximately 21 per cent, due largely to the elimination of

overtime (Tables 1 and 2), making the total saving from these two items $268,728.12 per year. From this should be deducted $10,839.12 for maintenance of the distribution system, leaving $257,889 as the net operating saving per year due to electrical operation.

The roadmaster states that it is quite evident that the electric locomotives are much easier on the track at curves but that there is no noticeable difference on tangent track, and that while sufficient time has not yet elapsed to form definite conclusions, present indications lead him to expect that any difference relative to his work will be favorable to the electric locomotives.

Arranging the items of expense appearing in Table 6 in the order of usual appearance in the summary of a standard locomotive performance sheet, and placing them on a yearly basis, results as follows:

Item of Operating Expenses	Steam 1913	Electric 1914	Decrease 1914	Per cent Decrease
Fuel and power	$315,235.74	164,508.70	150,727.04	47.81
Repairs	124,787.90	92,278.08	32,509.82	26.05
Enginemen's wages	104,461.18	71,225.88	33,335.30	31.81
Enginehouse exp.	29,907.80	18,638.38	11,269.42	37.68
Water	4,953.66	1,193.70	3,759.96	75.90
Lubricants	9,751.44	4,942.32	4,809.12	49.30
Other supplies	5,823.52	4,552.36	1,271.16	21.83
TOTAL LOCOMOTIVE PERFORMANCE	$594,921.24	$357,339.42	237,581.82	39.93
Trainmen's wages	147,632.30	116,486.00	31,146.30	21.10
GRAND TOTAL	742,553.54	473,825.42	268,728.12	36.19
Ton miles hauled	158,917,720	172,855,856	13,938,136*	8.77*

*Increase

The total cost of the electrification, including a change of signal system on Smelter Hill, the extra motor-generator set recently installed at Anaconda, interest during construction and all incidentals due in any way to the electrification, was in round numbers $1,201,000. This does not include the step-down transformers, which are the property of the power company, but on the other hand no deduction has been made for the salvage due to the elimination of 20 steam locomotives.

If a correction be made for the item of depreciation in Table 6, charging the regular monthly amount of $2711.13 begun in March for each of the six months making the total of this item

for the period $16,266.78 instead of $8,471.84 as it stands on the performance sheets, the total saving per year from locomotive performance would be reduced to $221,991.94, making the total net saving $242,299.12, which is equivalent to 20.02 per cent on the entire cost of the electrification, to say nothing of the increased capacity of the lines, the improvement in the service and more regular working hours for the crews, as is indicated in Table 5, comparing the delays to traffic, and Tables 1 and 2, showing the decrease in overtime.

From Table 7 it will be seen that if taken on the basis of the increase shown in net operating revenue, or operating income, this percentage is slightly greater, the rate of increase per year for these items being $288,150.80 and $282,016.96 respectively.

The estimate on which the decision to proceed with the electrification of the road was made, placed the annual net saving expected at 17.5 per cent of the cost, so that the results financially have been quite as satisfactory as the general performance of the equipment.

Discussion on "The Future of Electric Heating and Cooking in Marine Service," (Mauger), New York, May 19, 1914. (See Proceedings for May, 1914.)

(*Subject to final revision for the Transactions.*)

W. S. Hadaway: In reading this paper of Mr. Mauger's, the first omission that strikes me is the practical elimination of the electric laundry on board ship. It has been my experience that the adoption of electrically heated laundry machines, such as body ironers, combination ironers, as well as hand irons are an essential part of the equipment for the comfort of the men on an extended cruise.

When it comes to electric cooking my opinion is that the problem is not as simple, and that the solution is not as complete as would be indicated by the results stated in this paper. I think I can say that the paper is based largely on the trial trip of the *Texas*, plus a considerable amount of optimism.

As I recall the specifications used by the department, they were put out in 1910, and bids for apparatus have been asked for under them several times. The contractors who have bid under these specifications thus far have had to pay very dearly for their experience.

So far as the oven is concerned, the electric range can be made a complete success. I want to call your attention, however, to the fact that the ovens referred to there are equipped for an input of 1 kw. per cu. ft., which is an extremely high input, considering the input which well-insulated ovens are figured to have. My information shows that the average oven in the market runs more nearly 0.8 kw. than 1.00 kw. per cu. ft.

When it comes to the broiler, I believe the author is entirely correct in saying that the present radiant unit for broiling and toasting is entirely satisfactory. The only point where the electric range falls down, and falls down good and hard, is on the top surface cooking.

You will note that useful area for top surface cooking is given approximately as 37 by 24 in. It is my understanding that these top surfaces are made up of a series of eight plates, each of which is 9 by 12 in. On the basis of an input of 1750 watts per plate, this would make the input per square inch approximately 18 watts. It has been the result of experience that a density of 18 watts per square inch represents approximately only one-half the rate of work which can be obtained by the ordinary coal range. Furthermore, the temperature at which the electric hot plate works is so low, compared to the coal range, that the service obtained from the electric range is wholly unsatisfactory.

My own experience in this line of work dates back to 1894, twenty years ago this summer, when we made an installation on the receiving ship *Vermont*, then lying at the Brooklyn navy yard. At that time the galley attendants were all Japanese, and the ingenuity which they showed in their endeavor to

make that stuff work was amazing. They wanted it, but they could not get the work out on time, and we had to take the apparatus out.

The same sort of an equipment was in use for about eighteen months after that installation had been made, in the offices of the manufacturing company, and wattmeter readings of the work done were kept as well as records of the number of people served, and it was found that the input per person per meal was somewhat less than the figures given by the author.

As to my experience with the electric cooking proposition, I would say that there is no doubt as to the perfect success of the electric baking oven. I call attention, however, to the Navy specification which permits a loss of 40 watts per square foot, indicating heat insulation values which are relatively low. In fact, so far as I have data at hand for the moment, somewhat lower than we obtain in average practise.

The future of this work, it seems to me, is based solely on whether we can devise a durable structure that will do top surface cooking, such as frying, boiling, in small utensils, in a manner which will approach the results obtained on the older types of apparatus. It is too much to expect to get chefs, or people of that order of intelligence, to change the method of use. We have got to supply heat in relatively large volumes at high temperatures and make the apparatus speedier. The development of the chromenickel resister makes this possible. The difficulty in doing it, however, is the added load which we place upon the generator plant. In other words, if we raise the top surfaces up to the point where they would compare directly with the coal range, we would increase the watt capacity, the connected capacity of the range, from 31.6 to 45.6 kw.

E. F. Dutton: There is one point I think should be considered, and that is the quality of the baking. It has been the experience, I understand, on shipboard, that the product is so much better, and the waste is so much less, that this fact goes very far toward overcoming other apparent disadvantages of the electric cooker.

Of course, the first thing that is spoken of in looking at a galley is the cleanliness of the galley, and that is one of the inherent advantages of the electric range or oven.

H. J. Mauger: I think Mr. Hadaway's remarks are very much to the point, and he, like ourselves, would like to have hot plates that would be more rapid. I think, however, Mr. Hadaway has kept that figure of watts per square inch in his mind more than is necessary. I remember a paper that he read before the American Institute of Electrical Engineers some time ago in which he brought out the fact that a gas flame would develop 40 watts per square inch, whereas up to that time the usual hot plate that it was safe to design consumed around 10 watts per square inch. But in a coal range

on board ship the cooking top does not become equally hot. It is only over the coal box that it is hottest, and we have not found any complaint from the cooks on the score that Mr. Hadaway points out, that the cooking is any slower than by the coal method. Even with only 16 watts per square inch, it seems to be satisfactory for present purposes, and there are developments in the art which will soon enable us, doubtless, to go beyond that.

Mr. Hadaway referred to the development of the chrome-nickel alloy, which gives a remarkably fine resistor, but it is in the application of that resistor that we find our practical limitations. We have got to insulate that resistor electrically with something, and the thing usually used is mica. Mica dehydrates and breaks down at around 700 to 800 deg. cent., depending on the quality and the character of the mica, so that makes a limitation in that direction; one that prevents our operating at a higher temperature. But I think that when the hot plates are applied as in the range the heat is drawn from more than one plate into the vessel in which the cooking is being done, each hot plate contributing its heat—and in that way makes up for any theoretical lack in watts per square inch under the vessel, so that the cooks seem to be able to get the same results as with coal or gas.

Doubtless on the question of thermal insulation much can be done and much more will be done. I might say that there is a domestic range just recently on the market, having an oven which has remarkable thermal insulation, in which the current is cut down about half of what was formerly required. However, the larger the apparatus, the less relative radiating surface there is in proportion to the power that is used, so that the question of saving a few watts is not so important as it is when you are trying to cook in your own kitchen, at the lighting rate, within the means of your pocket-book.

Frank T. Leilich: The advantages of electric heating and cooking as set forth by Mr. Mauger can hardly be questioned. However, when viewed from the standpoint of cost, such applications of electricity can hardly be said to possess obvious advantages.

Aside from the illogical procedure of converting the heat energy of fuel into mechanical energy which is in turn converted into electricity and this finally transformed into heat, the electric range and oven are open to the following very serious objections:

1. High first cost.
2. High cost of repairs.
3. High operating cost.

The first and second objections may become less serious in view of possible improvements in manufacture of the apparatus. From the present outlook the third will, however, become of still greater importance than at present, owing to the increasing price of fuels.

As a matter of fact the fuel oil range is coming forward as a most serious competitor of the electric apparatus. The former combines relative cheapness of first cost with low cost of operation and ease of control. On the Pacific coast there are in operation a number of highly successful installations of oil ranges. Low pressure oil delivery is used in most instances. The most serious objection to oil is the fire risk, but with reasonable care and a well-designed installation the danger becomes a secondary factor.

The best steam plants convert not over about 16 per cent of the heat energy of fuel into electricity and with the Diesel engine, the most efficient prime mover known, not more than about 30 per cent can be converted. It does not seem unreasonable to suppose that an oil range can be made in which at least 40 per cent of the heat of combustion is available at the heating surfaces.

Assuming a ship with a crew of 1000 men and taking Mr. Mauger's estimate of 1.25 kw-hr. per man per day as the requirement for electric cooking, the daily costs of electric and oil operation would be about as follows

1250 kw-hr. of electricity at 1.0 cent ....$12.50.
83 gal. of oil at 4.5 cents ....3.74.

The oil consumption is based on 40 per cent efficiency of the range and B.t.u. requirement per day per man equivalent to that produced by 1.25 kw-hr. The heating value of the fuel was taken 18,000 B.t.u. per pound.

If repairs and investment costs are considered, the oil range will make a still better showing than indicated by the above figures.

DISCUSSION ON "ELECTRICITY THE FUTURE POWER FOR STEERING VESSELS," (HIBBARD) NEW YORK, MAY 19, 1914. (SEE PROCEEDINGS FOR MAY, 1914.)

(Subject to final revision for the Transactions.)

G. A. Pierce, Jr.: We do not agree with the author that the American navy has been the most conspicuous exception to the limited use of electricity in marine work. In 1902 on the Russian battleship *Retvizan*, building at the time the U. S. S. *Maine* was building, the generating plant was 528 kw. compared to 328 kw. on the *Maine*. Remote control contactors were used exclusively in connection with turret turning, ammunition hoists, elevating and rammers, which at that time had not been contemplated in the American navy and only used to a limited extent in this country. Six-inch bilge pumps were operated by 60-kw. motors, six in number; electric steering gear; electrically driven forced draft fans; six-pounder and three-inch ammunition hoist operated by remote control—none of which was in use or contemplated at that time in the American navy. Furthermore, the step-by-step motion for interior communication apparatus, recently adopted by our navy, was used. The majority of the systems were copied from the French navy at that time. Prior to the adoption of electric heating in the U. S. navy ships, several merchant vessels were thus heated, not only in America but in England, and the extended use and development has been retarded owing to the lack of engineering in connection with these early installations. Electric steering gears, windlass and capstans and in fact, every use in which electricity is at present employed, has been previously used both in merchant marine and other navies.

While our recent achievements are very creditable, we should not look on them with too much pride.

Referring to the question of control of steam steering gears, I thoroughly agree with the author, particularly when I recall one installation in a cruiser with shafting from the pilot house to the steering engine room. When the vessel was loaded and maximum temperatures were reached after all fires in the boilers had been lighted it was impossible to move the shafting and resort was made to the electric telemotor which previously had been installed as an auxiliary, and this electric telemotor was used to operate the vessel thereafter, although the system of shafting was made to operate with some degree of success. In most steam gears where hydraulic telemotors are used, it is customary to supply an indicator to tell when the transmitter and the receiver of the hydraulic system are in synchronism. This is required because of leaks in the system, and clearance in the pistons.

Referring to the results to be accomplished by electric steering, we do not agree with the author that the noise has been greatly reduced, especially with the system using contactors, as their constant operation is attended with noise. Furthermore, the electric control is not, in my opinion, the simplest means of control, as we can conceive of nothing simpler than the wire rope

transmitter with Hanscom drum for operating a steering gear, and any troubles are more easily traced and found than is possible with an electric gear, with all the electric wiring and circuits and its multiplicity of contacts.

Referring to the history of electric gears, we desire to take exception to the author's statement that in recent years, only, has the matter been given sufficient attention and the electric apparatus developed to such a point as to permit of successful results being obtained, and we point to the succeeding page of the paper for illustrations of early and successful steering gears, namely, Russian ships, *Finland*, *Minnesota*, and *Dakota*, and we believe these were not only some of the first, but the first successful electric steering gears used.

The remainder of the paper is devoted to the description of rheostatic control gears, and we note the author's remark " it is not the purpose of the paper to draw close comparisons between the features and merits of the various systems." We think, however, in view of some other statements in the paper, some further remarks relative to other systems are essential.

If we approach the question of electric steering gears from an engineering standpoint on the basis of the requirements laid down, we require the following:

A gear for frequent starting and stopping and for short movements to right and left of central line, for maximum torque regardless of speed, as the speed depends on the design of the gear used, easy starting and stopping to prevent wear, one with a minimum number of parts and contacts to become deranged. If a maximum of the above can be obtained in one gear the question of per cent efficiencies drops into insignificance, so long as the gear is not positively wasteful.

The speaker is of the opinion that the Pfatischer gear comes nearer the solution of this problem from an engineering standpoint than the rheostatic control, although, commercially, the rheostatic control may have some advantage.

The rheostatic control as applied to steering gears appears not to be the engineering solution of the problem. The line current with full line voltage for every movement is used with the resistance to control the amount of energy for the work to be done, and this seldom amounts to the rating of the motor when compared to the number of operations, and in that event a brake is applied to stop the momentum imparted. It should be noted that 20 seconds is usually the longest time run, and during this period to start the motor, eight or ten contactors are used to bring the motor to full speed, dynamic braking as well as disk braking to stop the operation and a limit switch installed to prevent over travel.

The pumping of so large a motor is sure to affect seriously the voltage of the entire system, as we note from the curves, 10 peaks of 1600-amperes or 200 kw. in approximately two minutes.

Relative to the follow-up gear, it does not appear in the paper,

and we have never been able to obtain satisfactory explanation of what advantage is to be obtained by its elimination. It is an automatic stop for the system, as well as an indicator of the position of the rudder at all times, and when not installed its functions are supplemented by a rudder indicator which is very seldom installed on merchant vessels, and also by the automatic spring in the reversing switch on the bridge, as described in the paper, to operate in the event of accident to the helsman. It is our opinion that the advocates of the non-follow-up system are misguided.

In conclusion, the electric steering gears as designed, installed and operated successfully for twelve years, have perhaps one-tenth the pieces of apparatus and one-thirtieth the number of connections of the gear advocated in the present paper, and as the author of the paper was intimately connected with the selection of the steering gear for the *New York* and *Texas* it would be interesting to know if the decision was reached on an engineering or commercial basis.

Mathias Pfatischer: In regard to the criticism that a small Pfatischer gear as installed on the cruiser *Montgomery* requires a current consumption of 25 amperes at all times the rudder is not being operated, I looked up my records and found that the amount is about one-half of that stated.

As regards the difficulty mentioned of getting a sufficient operating voltage by the use of the Wheatstone bridge connection, I have never found such to be the case. As a matter of fact I could get about 40 volts on the third contact from zero, and nearly full voltage on the sixth point. I have found that for successful electric ordinary steering of a steamer not more than about 40 volts are required; it varies from about 10 to 40 volts across the steering gear motor armature terminals. Full voltage is required only on rare occasions. This indicates to me that a constant voltage system will hardly constitute a proper solution. I have found in my work in the past that the amount of power required for steering a straight course across the Atlantic is very small. On the Red Star liner *Finland*, which is of 10,000 tons and has a speed of 16 knots, the current consumption never exceeded 15 h.p.

I cannot agree with the author of the paper that the steering gear which he has described marks an advance in the art and believe it has never been tried out under adverse conditions, such as, for instance, in steering a ship through a crooked channel. It seems to me it is considerable of a disadvantage for the quartermaster to have continually to watch the rudder indicator, because it distracts his attention. He should be looking at the compass and the bow of the ship instead of the indicator. He should know that when he moves the steering wheel or pointer to say five degrees right or left that the rudder would move to that point and stop automatically, without his having to pay any attention to the rudder indicator so he may know when to cut off

the electric power. The gear described is not fool-proof, which a successful electric steering gear, in my opinion, must be.

Maxwell W. Day: In referring to the systems using motor-generator sets, criticism has been made concerning the weight, size and cost, but there are certain advantages which should not be overlooked.

1. It has been shown that the starting peaks on the *Texas* gear amounted to 1600 amperes with a 150-h.p. motor. With a 350-h.p. motor these peaks would naturally be taken up to over 3700 amperes for a 120-volt ship, and further, the more rapid movement of the rudder from hard over to hard over will increase the working load more than in this same proportion. Mr. Hibbard has called attention to the fact that when the ship is turning from one extreme position to the other, the rudder requires greater power than when the rudder is moved from mid-ship position to the outboard position.

In some tests made in the German navy a few years ago, it was found in going from hard over to hard over that the maximum pressure was obtained at about 30 degrees rudder position, instead of 38; the pressure being 71 tons at 30 degrees, while the pressure calculated from Middendorf's formula for 38 degrees shows 35.5 tons. On this account, a steering gear to operate at the high speed required on the recent ships, will require more than twice as much power as if the rudder were to move at one-half the speed.

On this account, the rheostatic system for some of the later ships would require contactors capable of operating with 4000 to 4500 amperes, and this, in itself, is a serious problem. If the use of these large contactors is to be avoided by the use of two motors, each of one-half capacity, a much larger number of contactors of smaller size is required, and the system of connections and interlocks becomes very complicated, especially if a series parallel or parallel series arrangement is to be used.

With a motor-generator, the contactors required for starting up the motor-generator set are very few in number and seldom used; so that the conditions for the few contactors required are very much more favorable.

2. With the rheostatic system a heavy peak of current is occasioned at the instant of starting and a large amount of energy is dissipated in the starting rheostat every time the motor is started. With the shunt motor the energy lost in the rheostat is practically equivalent to the kinetic energy of the armature at the speed required at the time the rheostat is completely cut out of the circuit, and with a compound motor somewhat less.

This is not mentioned on account of the question of efficiency, as the running light losses of the motor-generator set probably just about offset it, but this system of starting requires a heavy load to be put upon the generating plant, practically instantaneously, and as the rudder in many cases is moved four times a minute, this produces a sudden fluctuating load upon the generat-

ing plant, which is objectionable from an operating standpoint, and criticism of this has been made in some cases. On the other hand, the motor-generator system avoids these peaks, because the motor is started up without the insertion of resistance, and the load is gradually applied to the motor by the building up of the field of the generator, and during the time that the rudder motor is operating at low speed, and requiring a correspondingly low voltage from the generator, the power taken from the generating plant is relatively small.

In addition to this, the compound winding of the motor-generator set slows down the speed as the load is applied, thus transforming a portion of the kinetic energy for the accelerating of the rudder motor armature.

3. As the rudder torque increases very rapidly as it is moving away from the midship position, it is desirable to increase the torque per ampere of the motor, which is done in the rheostatic system either by using a compound-wound motor or by automatic strengthening of the field of a shunt motor, but in addition to this feature, the generator of the motor-generator system is provided with a drooping characteristic by means of a reversed series winding, so that the amount of power required is very much reduced, and this same effect is increased by the compound winding of the motor of the set, which reduces its voltage still further by reducing the speed of the generator. In this way, the power taken from the generating plant is increased at light loads and reduced at heavy loads, to a greater extent than is available with a compound motor, working on a constant potential system with rheostatic control.

4. Further, with rheostatic system, the stopping of the rudder motor armature is accomplished by a dynamic brake and a mechanical brake, so that the kinetic energy of the armature is transformed into heat; but in the case of the motor-generator system, a considerable portion of this energy is stored up again in the increased speed of the motor-generator, and will be available for use at the next time that the rudder motor is started.

What has been said concerning the motor-generator system, applies, to a considerable degree, to a separate generator operated by its own prime mover, except that with a regulating governor used on generating sets, the speed of the generator will be practically constant, and therefore, does not have the same advantage in storing up kinetic energy at increased speed.

5. Reference has been made to the Pfatischer system. This system is provided with a follow-up control. It has the advantages mentioned above as applying to motor-generator sets or separately driven generators, and has the further advantage that it allows the use of an extremely simple type of follow-up control.

Reference has been made to some of the Russian ships, and in this connection I will mention that the Russian cruiser *Pallada* and German cruiser *Aegir* were equipped with the Essberger gear. This consisted of two shunt motors running in opposite direc-

tions, connected to differential gearing. When the motors are running at the same speed, the rudder remains stationary. When the speeds are changed by shunt field control, one motor running faster and the other slower, the rudder is moved at a speed corresponding to the difference of the motor speeds.

These equipments do not have a follow-up control, and the German equipment was taken out, as it operated in a manner different from that of the customary steam gear.

R. A. Beekman: There are some values of current given in the paper under "Ampere Peak" and "Ampere Steady." Under, "Ship at anchor, full speed position," the "Ampere Steady" is given as 150, and at "half speed position" as 800. I would like to know how the 800 came about.

H. L. Hibbard: That is because in the slow speed position there was an armature shunt connected there, which allowed the current to pass around.

Mr. Pierce referred to the large number of installations effected on the Russian battleships some years ago, and I wish to explain that in the part of the paper in which that reference is made, I intended to convey the idea that the marine field in general was one of the least developed of any, that the American navy had developed this field more than the merchant marine in this country, and in my belief we had progressed further in the electrical field in the navy than any other nation in the world.

Mr. Pierce also asked what are the advantages of the elimination of the follow-up. In the first place a very decided advantage in the elimination of the follow-up is the simplification of the apparatus itself to the bridge, the control itself is thereby very much simplified. I think the control with the non-follow-up type is quite as simple as the Hanscom drum, and not any more liable to give trouble, consisting, a sit does, of one lead of cable containing three or four small wires, probably in one-inch conduit, and the contacts at the master controller are few, small and substantial.

In the second place, by the elimination of the follow-up system it has been clearly shown from the results that the response which is obtained is a little more rapid, and that the man at the helm does not have the same tendency to be moving the master switch as he does with the old wheel. In that case there seems to be a tendency for a man to move the wheel back and forth, whether any movement of the rudder is produced or not. Results, however, with the master switch control, of the non-follow-up type, show that he moves the wheel or lever only when he wants results, and he furthermore does not have to steer as much; that is, he can keep his ship on the course with fewer movements of the helm, owing in part to the very rapid response with this type of control.

As to whether the *New York* and *Texas* steering systems were decided on a business or engineering basis, of course, both business and engineering is involved in all these matters. In

the case of the *New York*, the lowest bidder obtained the contract for the installation of the apparatus, so that fact eliminates the question entirely as to whether it was decided on an engineering or a business basis. No matter which system was the low bidder, it would probably have been installed; that is, either of these systems was acceptable for these ships, and, therefore, they were on a free competitive basis as regards the business end of it.

As to the question of the *Texas*, I think I can say that the installation, as made, was not effected on a business basis, only, by a large percentage. Engineering considerations had a great deal to do with it.

Mr. Pfatischer has mentioned an error, apparently, that has been made in the amount of current consumed in the motor-generator set. I have simply to explain that the figures given there were furnished by a representative from the navy department, as secured from the *Montgomery* set, and if I am mistaken I will be glad to accept the correction.

As regards the use of the non-follow-up type of gear in harbors, etc., I think experience has shown that a man can steer in a harbor quite as well with non-follow-up as he can with the follow-up system, after a little experience, and tha the seldom needs to look at his indicator, does not need to know where his rudder is, and when in the harbor, can look on either side of the vessel, and see that he does not run into anything. I have stood beside a master switch and watched the helmsman, and find that it is only a question of watching the bow of the ship, or objects on one side or another, and he does not need to care where the rudder is. When the ship is at sea, and they are steering on a straight course, it is usually a question of watching the bow of the ship and the compass. When the vessel is in fleet manoeuvres or formations of that kind, it is important to know where the rudder is, and the indicator is then necessary.

With regard to starting peaks, which Mr. Day has referred to, and Mr. Pierce also, I will say since the paper was written, that on both the *New York* and the *Texas* the arrangement of connection and resistances has been changed. We found it was unnecessary to have such high starting currents or the armature shunt connection, so that the starting peaks, instead of being 1500 or 1600, as shown on the curve, are now 800 or 900, and as regards the load on one generator, or any number of generators, our trial of the *Texas* showed that even with the high peaks which were obtained, one generator could be used with the lighting load, and only a slight fluctuation in voltage beyond the normal noted. With two generators no change in voltage was noted, and with the reduction in peak one generator can readily be used without any fluctuation in the voltage.

As regards the 4000 amperes required for the contactor system, I will say that Mr. Day has himself already explained that to some extent. On one of the recent naval installations two motors have been installed, as stated in the paper, and the power

divided, so that any contactor does not carry more than about 1000 amperes as a maximum. The two motors are instrumental in cutting down the peak rushes of current, and minimize the amount of power required at the smaller angles, at cruising speeds, etc.

As regards the dynamic current required in stopping motors, I would say these motors are especially selected, and operate at low speed, that is, comparatively low, and it has been found that it is quite possible to stop the motors without the use of the disk brakes at all, if you wish to depend to that extent on the dynamic effect. It is not so necessary to stop the motors quickly when the non-follow-up system is used. When the follow-up system is used, you must stop them with the quicker acting dynamic brake, to prevent any possibility of following over.

As regards the two systems in general, there is no question but that the rheostatic system may have a few more small parts, while the motor-generator system certainly has a greater number of large parts, and the weight is much greater, and, of course, the first cost, which may be incidental, is greater. There are of the two systems now sufficient installations being effected so that in a short time we will have results of the total power consumed by the two systems, and it is my prediction that the rheostatic system will show a total consumption over a considerable period of time appreciably less than the motor-generator system.

H. A. Hornor (by letter): The advantages of the contactor type of steering gear control have been clearly set forth by the author of this excellent paper. The disadvantages may be briefly stated as follows:

Contactors may be prevented at times from properly functioning due to the rolling and pitching of the vessel.

They may also be affected by the vibration of the vessel, which at high speeds in this location is often very severe.

In general the mechanical as well as the electrical wear and tear on this type of apparatus occasions very careful supervision and upkeep.

The current demands on the generating plant are too great and too frequent. The latest requirements for the design of generators for naval service state that, for 300-kw. sets, the speed variation must not exceed 4 per cent when full load is thrown on or off; and 3 per cent when load is suddenly varied from full load to 20 per cent of full load, or vice versa, when operating condensing at normal steam pressure. The jump in voltage must not exceed 12 per cent, or 15 volts in the case of a 125-volt machine, when full load is suddenly thrown on or off, under all the varying conditions of steam and operation. The author of this paper gives ammeter records for a 150-h.p. motor, 60 per cent overloaded. Current peaks of 1600 amperes in short variable periods of time are indicated. This represents 3/4 load for one 300-kw. generator. In the case of a proposed 300-h.p. outfit this would mean full-

load current peaks of 2100 amperes, or nearly full load for one 300-kw. machine. If 100 per cent overload is demanded, the current peaks would double, requiring full-load current from two 300-kw. generators; or the full load capacity of the after dynamo room. There would remain for the general supply of current to the ship 1600 amperes, or the 1/3 overload capacity of the two generating sets. Under practical working conditions on shipboard the jump in voltage averages about 10 or 12 volts—an amount which will affect the lighting and perhaps other installations.

The disadvantages of the motor-generator control are mentioned in the paper and therefore the advantages will be stated;

No contactors in continual operation.

Reliability insured by staunchness of design.

Reduction of supervision and upkeep.

The omission of the electro-mechanical brake.

Reduction of current peaks, thereby cushioning the loads on the generating plant.

DISCUSSION ON "RELATIVE MERITS OF Y AND DELTA CONNECTIONS FOR ALTERNATORS" (EDEN) AND "DELTA AND Y CONNECTIONS FOR RAILWAY TRANSMISSION AND DISTRIBUTION" (DAVIS), PITTSFIELD, MASS., MAY 29, 1914. (SEE PROCEEDINGS FOR MAY AND OCTOBER, 1914.)

(Subject to final revision for the Transactions.)

John B. Taylor: As Mr. Eden makes no mention of changing the construction which has been followed for a long while, from Y to delta, as he advances no argument for doing it, and as I do not think that anybody has good argument for doing it, it seems that the matter is fairly well settled. The discussions which have held so long on transformers have never come up on generators, and to that extent the work is standardized in part and in a more satisfactory state.

It does not seem that Mr. Davis has brought out anything that calls for much difference of opinion. It might be well to add that the Y-diametrical connection, the equivalent of Y-Y, has been used considerably. I believe Mr. Davis said he saw no reason why it was not permissible. He might have gone a bit farther than that, perhaps, and said it had been in use for a number of years without, so far as I am aware, any objection to its use.

There is this peculiar thing about the Y, diametrical connection which is also true of the Y-Y connection, that when the transformer is excited, before the load is connected, you may read unbalanced voltages on your three diameters, and furthermore, these voltages, whether or not unbalanced, may be more than the ratio of transformation calls for. I remember in the case of one of the early Y-diametric installations, in Waterbury, Conn., it was feared to start up the converter, because the voltmeter across the low-tension terminals showed values higher than the ratio of transformation allowed, although the primary voltage showed values it should have shown.

This was another instance of the third harmonic cropping up. Before the converter was connected they were measuring the triple-frequency voltage combined with the normal, but the small magnetizing current which the converter readily supplied brought this down to zero.

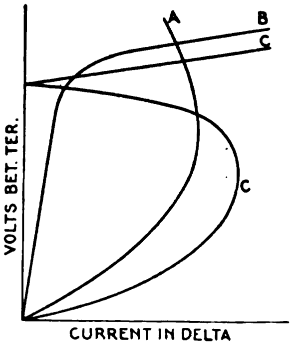
C. J. Fechheimer: Mr. Eden points out the advantages of the star connection for alternators, but does not bring out what may be the advantages of the delta connection. There are a few advantages, all of which have only limited applications, however.

The first is that, with the delta connections we can secure half voltage very simply. For example, if a generator is wound for 240 volts, you can tap at the mid point on each leg of the delta for 120 volts. That is often convenient for lighting, and still permits of use of 240 volts for power. It is better than the star connection tapped at points between the neutral and terminals, to obtain nearly 120 volts. It is also better than 240 volts between terminals for star connection with neutral tapped,

thus giving 138 volts, which is frequently too high for lighting purposes.

The second limited advantage of delta connection applies in large machines wound for low voltages. For example, in a 2000-kv-a., 240 volt machine, the winding with star connection would be extremely difficult; it may be almost impossible. The delta connection lends itself far more readily, since it permits of more turns, the difficulty being to employ a reasonably large number of turns per phase.

The third limited advantage occurs when we endeavor to use existing parts, such as existing punchings, for a voltage for which the machine has not previously been wound, and it actually simplified the connection rather than complicates it to use delta rather than star. For example, we may find for a certain voltage we want around $1\frac{3}{4}$ conductors per slot or equivalent thereof, for star connections. This would require 14 conductors per slot, 8 circuits, for a two-layer winding, or 7 conductors per slot, 4 circuits, for a single-layer winding. For delta connection we could use either 6 conductors, 2 circuit, or 3 conductors, 1 circuit, thus greatly simplifying the winding.



Mr. Eden shows in his oscillogram records, and in the subsequent analysis of the waves, how the delta current may vary. This refers to one or two examples, and does not cover the many cases which may arise. There is, possibly, nothing so erratic as the circulating current in the delta in the alternator. In some cases the delta current may be a curve like that shown as "A." The most common form of delta current is somewhat similar to that of a saturation curve, although usually the knee is more marked, as in "B." I have known one case in which the current rose gradually, dropped to zero and then rapidly rose, again as in "C". I shall not take the time to explain these peculiarities. Although I have not had opportunity to check experimentally, I believe that the curve of delta current in delta-connected transformers varies as much as in delta-connected alternators.

Mr. Eden shows how the delta current may be reduced, or practically eliminated, by using a $\frac{2}{3}$ pitch winding. I do not think that that is the only way in which it can be reduced. For example, by inserting a sufficient amount of impedance at the apices of the delta, and tapping these impedances at their mid points, one can greatly reduce the amount of circulating current. The same effect can be accomplished by the use of magnetic wedges in the machine, which increase the internal reactance. We can, by carefully proportioning the parts of the

magnetic circuit, (for example, by carefully designing the shapes of the pole shoes), also greatly reduce the amount of circulating current. In some cases it may be an actual hardship to use a $\frac{2}{3}$ pitch winding, because this means that a greater amount of copper must be used per slot than if the full pitch winding were employed, and for this there may not be sufficient slot space where existing parts are used.

I also want to point out that circulating current is subject to change with load and with power factor. The circulating current which is ordinarily measured is that which flows when there is no load on the machine, and as soon as we put a load on, the wave form is altered. At zero power factor one gets an entirely different wave than that which obtains at unity power factor. The distortion of the magnetic field unquestionably also distorts the electromotive force wave. That may introduce harmonics which were not present before, or, if present, were probably in the wave to a different degree, and may consequently materially alter the magnitude of the circulating current. Therefore, even though the circulating current was negligible at no load, it may not be negligible at full load, or vice versa. This is something that one must guard against in large machines as they are designed at present; that is, with poor regulation, and comparatively small air gaps, the flux distortion is much greater than it was in machines of some ten years ago, when they had close regulation, comparatively long air gaps, and the flux distortion was comparatively small. I think possibly that also in delta connected transformers, the load and power factor may have some influence upon the circulating current. I have not given this much thought, and I suggest this in order that those who have been working on this line may investigate further.

The author calls attention to the effect of the circulating current upon efficiency. I want to point out that I do not think efficiency is nearly so important in this connection as temperature. Circulation current may introduce temperature rises, which may be of serious magnitude; especially would this be the case under load if the distortion of the flux were such as to cause a considerable circulating current. In such a machine, then, the only proper way that one could make an accurate temperature run would be to put full load on it.

E. G. Merrick: I would like to make a few remarks in connection with Mr. Eden's paper, with especial reference to turbo-alternators. Mr. Eden and Mr. Fechheimer pointed out that in the salient-pole machine harmonics can be reduced very considerably by the proper proportioning of the pole faces. For the usual ratios of pole arc to pole pitch this gives a maximum gap at the pole tips which is about double the minimum gap. In the modern turbo-alternator, which is now usually built with a cylindrical rotor, we have a uniform air gap and the above result must be obtained in another way.

A fully distributed field winding, one which would correspond

to the winding of a direct-current armature, will produce a triangular magnetomotive force curve, the apex of which corresponds with the center of the pole. On the other hand an entirely concentrated winding will give a rectangular magnetomotive force curve.

It is evident that by proper proportioning of the wound and unwound portions of the pole pitch between these limits we we can get a magnetomotive force curve which approaches very closely to a sine wave.

Neglecting saturation, any harmonics which exist in the magr etomotive force curve will appear in the flux wave, and again, these harmonics will appear in the same way in the electromotive force curve, modified by their respective winding factors.

If the ideal rotor winding is obtained—viz., that in which the wound portion occupies two-thirds of the pole pitch, we will get practically a sine curve of m.m.f. and the third harmonic and its multiples will disappear. It is therefore usually possible to design the non-salient pole type of machine so that it can be connected either in delta or in star.

Mr. Fechheimer has just made a statement in regard to the third harmonic being influenced by the load. Tests on the non-salient pole type of machine do not, however, indicate such an effect. This is shown as follows: Measurements on a delta-connected machine under load indicate a certain current X in each line and a current Y in the delta, Y being greater than X on account of the additional current due to the third harmonic. At no-load and normal voltage we get a value Z for the circulating current in the closed delta and the combined currents X and Z will equal the above current Y. This would indicate that the value of the circulating current due to the third harmonic has not been changed appreciably by the load.

C. J. Fechheimer: How many machines was that carried out on?

E. G. Merrick: I have tried it on a number of different machines.

C. J. Fechheimer: What kind of load?

E. G. Merrick: On non-inductive load.

C. J. Fechheimer: That is contrary to my observations.

E. G. Merrick: In each instance the calculated results have come within the limits of error of reading.

C. J. Fechheimer: You must recognize the fact that the circulating current due to higher harmonics is not directly additive to the load current. I see you combine it in quadrature.

T. S. Eden: There is no question that by using a proper width of pole face, in per cent of pole pitch, the third harmonic can be avoided. The alternator, on the wave forms of which I made an investigation and reported the results in the paper, was one in which the percentage of pole face to pole pitch was only 52 per cent. Had this been $\frac{2}{3}$, the third harmonic current would have been largely eliminated, and there would not be any such value as 60 per cent in the fundamental.

R. E. Doherty: There is one point that just occurred to me in the way of an explanation of the discrepancy between the observations of Mr. Fechheimer and Mr. Merrick. Mr. Fechheimer says that he has noted no change in effect of the circulating current in the delta under load, and Mr. Merrick has noted that it has been appreciable. I wonder if the possible explanation is that since this change that Mr. Fechheimer pointed out is due to a change in relation of the center line of flux from the center line of the pole, whether the use of different proportions of minimum gap to maximum gap in the two machines on which this thing had been tried out on does no account for the discrepancy in observations? In the machines Mr. Merrick has referred to, he has pointed out that the maximum gap was something like twice the minimum gap. I wonder if this relation holds in the machines Mr. Fechheimer referred to?

C. J. Fechheimer: It does not.

E. G. Merrick: The tests I referred to were on smooth, cylindrical rotors, turbo-alternators.

C. J. Fechheimer: If the armature reaction, even in the turbo-generator in which the winding on the rotor is distributed, were sufficient to distort the flux, I should think the effect of the circulating current would be altered in most cases by change in load. I have not made any observations myself on turbo-generators in this regard, so I am not able to speak from experience. I am only theorizing. The machines I had in mind were definite pole alternators, in which the minimum air gap was but little less than the maximum air gap. By minimum air gap, I mean the gap at the middle of the pole, and the maximum at the edges of the pole.

R. E. Doherty: The condition, as I see it, is due less to difference in armature reaction than the spread of the exciting coils, which increase in reluctance in one case from the center of the pole to the edge, this difference being greater where the ratio of minimum to maximum gap is large than where it is more nearly uniform. The distorting effect of armature reaction would shift the flux a great deal more in the uniform gap.

Cassius M. Davis: I wonder if there is not a simpler explanation for that. In the transformer the triple harmonic exists whether there is load or no load, and the triple harmonic exists in about the same magnitude. It is not so noticeable in its effect upon the wave shape at load because the load current is so much greater than the triple harmonic current. Leaving aside the effect of flux distortion, I wonder, if the circulating current in the delta is not there all the time in about the same magnitude, whether there is a load or no load, but in measuring the voltage or taking an oscillogram across the phases, the wave appears smoother at the load, due to the reactance drop through the armature winding, while the triple harmonic may still exist there. This is analogous to the exciting current of a transformer, which stays about the same, regardless

of the load, and is too small to appear in an oscillogram taken across the terminals.

John B. Taylor: Bearing on circulating current losses in a delta-connected generator, I recall tests measuring directly the triple-frequency voltages in windings of a generator by connecting in Y and reading between common connection or "neutral" of generator and a true or stable neutral of transformer bank. These triple-frequency readings changed as normal frequency load on the generator was increased or decreased.

With a delta-connected generator, I suggest measurement by ammeter or oscillograph of the three currents (two in generator windings and one in external lead), at a corner of the delta. By this means, amount of circulating currents at different loads and excitations may be determined.

Selby Haar: I speak in defence of the delta connection from the operator's standpoint. As long as conditions are likely to arise in service, which make it necessary to operate damaged but partly serviceable generators temporarily, we cannot spare the delta connection. Anyone who has been able to maintain three phase service with two transformers connected in open delta will agree with this statement.

Mr. Eden reports 83 per cent of normal load current in one case. This current could be reduced to a harmless value by inserting reactances which, preferably should exhibit a proportionally higher reactance to harmonics than to the fundamental of the current wave; in view of some present tendencies of design, the increased reactance at normal frequency would not be altogether undesirable. Each reactance would consist of an iron core wound with a coil of several turns from the middle one of which a tap is brought out. Each corner of the delta is opened, and the two leads connected to the ends of a reactance coil, the tap being connected to the line. Suppose such a coil to have $2n$ turns, then the current at fundamental frequency in one group of n turns (on one side of the tap) is 120 degrees out of phase with the current in the other n turns, and the resultant magnetomotive force of both will equal In, taking I as the current per phase. The current of triple frequency, however, flows in the same direction and is of the same phase in both parts of the coil, so that at current I, the magnetomotive force is $2In$. Thus the reactance (below saturation of the iron) should be 6 times as great for the triple harmonic, and 18 times times as great for the 9th harmonic as for the fundamental. Of course the saving realized by the smaller circulating current in the generator is partly offset by the iron and copper losses in the reactances.

Where there are no insulation difficulties on account of high voltages nor space restrictions (as to shape and sizes of reactances) to contend with, the three coils may be wound on one core. Now the odd harmonics in the wave of e.m.f. (or current)

may be divided into three groups of the orders $3a$, $6a-1$, and $6a+1$, where a is any positive integer. The resultant magnetomotive force of these three coils, when supplied with balanced three-phase currents at fundamental, $6a-1$, and $6a+1$ harmonic frequencies is zero, while the three individual triple, ninefold, fifteenfold, etc., frequency magnetomotive forces are in phase. Hence the impedance of such a device to all harmonics of order not a multiple of 3 would consist of resistance only. Since, as stated, all harmonics above the third were practically negligible, the effect of such a coil should be very marked in this case. It would be interesting, as a check on this conclusion, if Mr. Eden could supply an oscillogram of the circulating current in one of these machines; it should show only the $3a$ harmonics. We should not give up the delta connection, simply because it is difficult to design a good delta-connected generator.

DISCUSSION ON "EXPERIENCES WITH LINE TRANSFORMERS," (ROPER), PITTSFIELD, MASS., MAY 28, 1914. (SEE PROCEEDINGS FOR MAY, 1914.)

(Subject to final revision for the Transactions.)

W. S. Moody: I think that manufacturers and designers of transformers owe a great deal to Mr. Roper for the preparation of this excellent paper; not only because of the information that it contains as to experiences and opinions, but because it is a little unusual to give so fully the experience of the user of apparatus, to the manufacturer. However scientifically and carefully apparatus may be designed, there are, of necessity, a great many things that nothing but service will demonstrate, and the manufacturer cannot benefit by that experience in service to any great extent without the very complete assistance of the operating man, and that assistance is not always available. The operating man is rather inclined to look at these figures as his private property, and the manufacturer does not get the full benefit of them.

I think the operator is sometimes inclined to criticise the manufacturer for being slow in complying with the suggestions and criticisms of those who use his apparatus, but I do not think there is any danger of this criticism being justly applied when data as complete as Mr. Roper gives in his paper are available to guide a manufacturer in his decision as to whether a change is necessary or not.

The whole question of reliability of apparatus, and transformers in particular, is essentially one that needs just this cooperation between the manufacturer and the user. The manufacturer, if he wants to establish such a reputation as every manufacturer should seek to establish, naturally wants to make his apparatus just as reliable as possible, but, as Dr. Jackson has intimated, it is possible to spend money that is not justified in attempting to get extreme reliability, and consequently it is only by keeping very exact records as to reliability, that the point at which it is economical to have additional factors of safety can be determined; but I think there is, after all, not much danger of the reliability side of the question being overdone.

Cost, low weight, small size, high efficiency, and in fact every other desirable point, are diametrically opposed to the features that go to make up long life; consequently, there is little chance that either the manufacturer or the user will be over-concerned with reference to reliability.

A. D. Fishel: It has been stated by Mr. Roper that the distributing transformer naturally forms one of the most important links in a large distributing system; further, that it has been one of the most able relilinks in that system. The distributing transformer has always been located in a portion of the system where it received comparatively little attention. However, we now come to a point where more attention is to be given to proper protection of such transformers, in addition

to the improvements in the transformers which have been effected during the past few years, and there is no doubt that the results should lead to more reliable service. It is important, of course, that the distributing transformer should be thoroughly weather-proof, as efficient in operation as possible and absolutely reliable from the standpoint of safety. In a large system, characteristics that become of special importance, are those features that lead to continuity of service. There have been marked improvements in the design, construction and manufacture of distributing transformers during the past few years and each one of these three items has some effect in determining the life and the reliability of the transformer, as well as tending to provide continuity of service.

These improvements in the small-capacity distributing transformers were largely made during the time that the alloy sheet steels were being adopted. It was the endeavor, with that development, to obtain in the design of such transformers, a balance of all of the many characteristics that are desirable for a distributing transformer, and these included the characteristics that tend to reliability and continuity of service.

The changes in design which accompanied this development, usually tended to increase the factors of safety in the design. In considering the desirability of some detail of design, all of the factors must be considered, because such a detail might not be suitable for one particular design only because it was not backed up with sufficient safety factors at other points or because of insufficient space to permit proper application, etc. This fact applies to the matter of the location of the transformer terminal board.

As I understand Mr. Roper's paper, most of the transformers referred to in Table III are not of the particular types or designs that are now available on the market. Therefore it is doubtful whether a safe conclusion concerning such a detail of design, as based on these data, can be reached with regard to present types of transformers. The modern transformer probably has greater factors of safety in the insulation, more uniform temperature rise and similar qualities that lead to a more reliable transformer and therefore it can be provided with a terminal board that will operate safely and to some advantage at the oil level. Thousands of transformers of such construction have been giving very satisfactory service.

Such transformers necessarily have greater clearances at the terminal boards and possess other differences in design. There was obtained the advantage of the terminal board providing a support to the leads about midway from where they issue from the coils to where they enter the outlet bushings. Another advantage was the absolute prevention of the siphoning of oil from the case, which Mr. Roper states is one of the petty annoyances met with in operation. In fact, I believe that there has not been a single complaint about siphoning of oil

under any reasonable operating conditions, out of tens of thousands of such transformers in service.

The location of the terminal board will depend largely upon the design of the transformer, the clearances available and the operating stresses which may have to be met. For distributing voltages considerably higher than the 2200-volt classes referred to in this paper, I do not believe that it would be advisable to have a connection board at the oil level. This, for example, would apply to 6600-volt, high-tension distributing transformers. With such transformers, the clearance distances, as well as the terminal board itself, would have to be too large, requiring much more space than is necessary to effectively apply the same on transformers of lower voltage.

After all, the most desirable development would be the elimination of a high-tension terminal board, and that brings up the question of voltage standardization. It is very desirable from many standpoints that voltages and taps should be standardized. On these small transformers, where continuity of service is to be a criterion, multiple voltages and extra taps should be eliminated wherever possible and one of the main functions of the terminal board will be automatically eliminated. It would therefore be very desirable to adopt single voltages on distributing transformers on the high-tension side, where, of course, such simplification is more important than on the low-tension or secondary side.

With a single high-tension voltage, the terminal board could most successfully be replaced with porcelain spacers approximately at the oil level, to provide the desirable support for the leads, without impeding the circulation of the oil and keeping the high-tension spacer separate from the low-tension board, so that there would be less possibility of the lineman making a mistake in handling.

With regard to the handling of the transformers, some of those now available have lugs, for lifting, cast on the sides of the case and these lugs form a convenient method of pulling the transformers around the floor, so that the leads should not have to be used for this purpose. With some of the modern transformers, the connection to the weatherproof cable leads is made inside of the porcelain outlet bushings, so that it requires considerable mishandling of the leads to injure the transformer insulation, especially with the more substantial high-tension bushings which are now provided.

Considerable attention has also been given, during the past two or three years, to the fuse block question, and porcelain fuse blocks of the receptacle and plug type are now available which are much more reliable and embody most of the characteristics which Mr. Roper sets forth as an index to a good transformer primary cutout.

I believe that Tables No. IV and V refer to electrical performance of the later types of transformers, while they are

considered in connection with the operating records of transformers of older designs and construction, which would not possess these electrical performances. Changes in the electrical performance may be accompanied by changes in construction that would considerably affect the operating record.

It would seem to be doubtful whether the reduced electrical stress on transformer insulation due to better protection would have any direct effect upon the life of the insulation. Fatigue of the insulation would only come if the stresses were of prolonged duration so that heat stresses would develop, while high-frequency or lightning disturbances are of relatively short duration.

There is no doubt that the better the protection against lightning disturbances, the more reliable will be the operation. There is considerable doubt, however, as to the number of such arresters which it would be practical to install in the average system. Each arrester means an additional link in the system which must be given a certain amount of attention to insure being in good operating condition. Further, the cost for obtaining grounds for each of these arresters would in many cases be higher than that in the city of Chicago, where grounds may probably be obtained at a fairly low cost. Of course, one must have a good ground to have an effective arrester.

It would be desirable to have an accelerated life test as an index of the reliability of the transformer, but it is going to be very difficult to determine on anything in the way of a reliable accelerated life test on a static transformer, such as may be obtained on moving apparatus, as the conditions are vastly different. Practically all that we can do is to study the service conditions, the material that goes into the transformer, see that it is put in in such a way that it will be permanent, that the insulation is properly reinforced, that the temperature rise is low and uniform and look into the various other details of design, construction and methods of manufacture that may affect the relative life of the transformer, but it is very hard to provide any single test as a real measure of such life.

H. W. Hough: As far as we have been able to find out in Cleveland, our experience checks up with Mr. Roper's statement regarding the Chicago conditions. We had approximately ten thousand transformers in service during the past year, and of that number about four hundred were brought in classed as burned out, whether from the coils being burned out or the leads or terminal boards being damaged. It was a fact that in the great majority of cases the terminal boards were damaged, whether the other effects were there or not. About ten per cent of our transformers have submerged terminal boards, and during the past year there has not been any case on record where the terminal board was damaged when it was submerged. I thought perhaps this statement would add a little to Mr. Roper's side of the question.

Paul M. Lincoln: If we take Mr. Roper's paper at its face value, he apparently has demonstrated that the submergence of the terminal of the connection board is a highly desirable thing in the distributing transformers such as he deals with. I would like to raise the question as to whether Mr. Roper has completely proved that point.

One of the points I want to call attention to is Table No. VI. In Table VI I think Mr. Roper has shown beyond a question that if a lightning arrester is used in connection with distributing transformers the burnouts of the transformers are considerably reduced. His own records show that the burnouts of transformers when a lightning arrester was used on the same pole are about one-third as great as when lightning arresters are not used upon the same pole. Now, a lightning arrester is merely a weak point (usually an air gap) which is used in close proximity to the transformer. I may call attention to the fact that a terminal board which is inside of a transformer serves the same purpose, it is a relatively weak point which lightning can break down. A great disadvantage of making the terminal board or connecting board the weak point is that when lightning does puncture at that point, it blows the fuses, and you have an interruption of service on that transformer, and that is admittedly an objectionable point. I do not believe that this demonstrates that we should not have a connection board above the oil in the transformer, but it should be a connection board having an amount of clearance which makes it, not impossible, but highly improbable, that the lightning will go across inside. That is to say, the design of such a terminal board should be such that it is as strong as the distributing line which is in immediate proximity to the transformer. If you have a terminal board of such a design, that is, so that lightning will go across on the outside of the transformer rather than on the inside, then I think any objection to the terminal boards is removed.

There is one point upon which I want to agree with Mr. Roper, and that is upon the use of fuses for overload protection. Mr. Roper states that the fuse cannot be relied upon an as overload protection, and I believe thoroughly in that point of view. The fuse, when it is used in connection with transformers, is primarily used for the purpose of interrupting short circuits or interrupting something which would cause the service to be interrupted at other points than that one particular transformer, and that is, I believe, its only function. I do not believe that it is possible to design and operate fuses upon our distributing transformers of such a nature as to protect them against overload. I think such a use of a fuse is practically out of the question.

I was very much interested in what Mr. Roper said about the accelerated life test. That is not a new idea, by any means, and if we could find some means of condensing the years into hours, in so far as the life of the transformer is concerned, we would be

very glad to get the results which we should get by such an accelerated life test, but so far, we have not been able to devise any means to accomplish that result, which we believe will be of very great value. If you run the transformer at double temperature for a day or two, that does not give the same result on this transformer as running it at moderate loads for several years, conditions are quite different, and whether the results obtained by overheating very considerably for a short period can be compared properly with the result of the normal life, is a very debatable question. Still, we are not giving up the question, and are still looking for some manner of accelerating the life of the transformer, so that we can crowd the life of the transformer into a few hours, instead of waiting for a good many years to elapse, to get information about the life of the transformer, such as we would have to do otherwise.

Joseph Franz: Representing one of the operating companies, I agree with Mr. Roper in general. Our troubles with the transformers in the Berkshires have been along the same line. Our experience in the matter of placing lightning arresters on the same pole with transformers has shown us that it is not always possible to obtain a good ground connection in isolated or remote sections, and we have had two cases where the lightning arresters failed. The current fused the gaps of a multiple-gap arrester and being connected on the same ground as the secondaries, this condition of the arrester sent the primary current into the building where the service was furnished, and set the building on fire. That caused considerable trouble to our company. Since we had this experience, we place no lightning protectors on the same pole.

Mr. Roper refers to the name-plate, and I would like to add that it would be an advantage to have the manufacturers standardize on the form of the name-plate, its arrangement, as well as having the reading matter in the same order, similar to the way in which the National Electric Light Association has standardized the meter dial faces, so that a man at a glance could read what he wished to read, without going over the whole name-plate.

In regard to the oil, I believe it would be better to adhere to the present practise, of having the manufacturers furnish the oil, as it would be very difficult for the smaller companies to select the proper oil for the transformers, and last, but not least, in case of failure the manufacturers could not lay the trouble to improper oil, if it was furnished by them.

M. O. Troy: Actual failures of transformers in service are represented by a very small percentage, yet it is very important that this percentage be reduced in every way possible, as each breakdown may constitute a risk to person or property. Inasmuch as we are dealing with such small percentages, any mere discussion on the part of engineers as to what will or will not decrease this percentage cannot settle the matter, and we have to resort to actual statistics such as Mr. Roper has collected and presented.

In many of our electrical devices, such as the flat iron or incandescent lamp, failure merely means the loss of that device, possibly a little complaint, and replacement if it has not given the service expected of it, but no particular damage is expected or done. The distribution transformer, however, occupies a unique field in that it is supposed to supply these devices uninterruptedly, to take the high-voltage energy, transform it and to permit the user to apply it to the various current-consuming devices with no misgiving and usually with no question as to safety.

Mr. Roper has pointed out, without resorting to theories or deductions, methods for obtaining greater safety and continuity of service, and has established his contentions by actual results of operation based on observation of hundreds of installations.

Mr. Fishel's plea for standardization is timely—1100 or 1200 volt plants are rapidly going out of existence, and the time has now practically arrived when, for a large part of this work, we can establish one primary voltage in the neighborhood of 2200 or 2400 volts—possibly as a compromise 2300 volts. This will enable the manufacturers to do away with connection boards, or else to use connection boards merely as lead supports, and with such liberal spacings as will not, under any operating strains, permit failure of the board. If, for convenience in some cases, it is necessary to supply connection boards, my experience, based on observation of hundreds of thousands of units, conforms to Mr. Roper's—namely, that it is better to submerge the boards.

Referring to Mr. Lincoln's contention that in some instances the unsubmerged connection board might be advisable to act as a safety valve by arcing across, blowing the fuses, and disconnecting the transformer; it would seem that this pre-supposes that the transformer strains, from lightning or high frequency, are from one primary to another. Is it not true that the lightning strains are more frequently from primary to ground and a relief of these strains, via the connection board, assumes that the lightning must, in some way, go from the connection board to the neutral of the secondary? Inasmuch as this method of breakdown is one of the very things we are trying to guard against, it would seem preferable to make the connection board, if it is used, as strong as possible, and to provide a safety valve—say lightning arresters—outside of the transformer.

Another objection to relying on the connection board to discharge high-frequency energy is that the discharge path consists merely of a small number of gaps with no resistance in series, and acts very much like an arcing ground, in that in the very act of relieving the strains, the arc itself may break down the windings.

A great many manufacturers are now carrying two lines of transformers within the voltage range under discussion, namely, 1100/2200 and 1200/2400 volt lines. It would be my recommendation that we supplant these with a line of one primary voltage—say 2300, with a density range in the core, making the

transformers satisfactory for operation under any range of voltage from 2100 to 2400; that we build the transformers as strong as practical consideration of costs, when balanced against results secured, will permit, and provide a safety valve in the way of a well-designed lightning arrester for use outside the transformer. This recommendation, I believe, embodies the standardization idea suggested by Mr. Fishel, and as far as I can see is in conformity with the recommendations which might be made, based on the statistics submitted in Mr. Roper's paper, and deductions which may be made therefrom.

E. E. F. Creighton: Only those who have been through the experience of collecting a mass of data, and under the various and variable conditions, such as exist on a large distribution system, realize how difficult it is, first of all, to gather reliable data, and next, to correlate these data in such a way as to draw any practical and useful conclusions. Breaking a path through any unknown region is always far more difficult than following one already made. The work of months can finally be expressed in a few brief tables and descriptions, giving no comprehension of the labor involved. Mr. Roper's information has been collected at a considerable financial outlay, and has called for careful organization of untrained men. From the standpoint of perfecting electrical protection, the investigation has a great value. It has done more than confirm the results of laboratory experiments. There has been added apparently a new conception of the nature of some surges which were considered harmless.

In the matter of deterioration due to successive strains in the accelerated life tests, it might be pertinent to state that such laboratory tests have been made. Mr. Roper's paper deals particularly with lightning, and in the duplication of lightning it has been possible in the laboratory to furnish any kind of a surge that is required—high frequency, high potential, steep wave front, sloping wave front, etc., and with these discharges accelerated life tests were made on transformers. In conjunction with this, different types of lightning arresters have been tested out at the same time.

In such tests, applied to many transformers, we have found that there is a deterioration from successive discharges. In nearly every case the transformer is able to withstand more than one discharge. Of course, the number of discharges that the insulation will stand is dependent upon the severity of the discharge, that is to say, in general, upon the voltage and the steepness of the wave front. The tests have shown that successive discharges will deteriorate some types of insulation, in somewhat the same way that a nail is driven through a board by successive strokes of a hammer.

All the laboratory experiments confirm Mr. Roper's statement that there is a deterioration carried on year after year due to lightning.

Very recently Mr. DeBlois gave a paper before the Institute,

at Washington, in which he showed oscillograms of lightning strokes which have different wave fronts, and gave us a very good idea, so far as it goes, of the different kinds of lightning strokes, which should be reproduced in the laboratory.

Briefly expressed, some of the salient points brought out by the data so far gathered are as follows: Doing away with exposed terminals reduces the troubles by one-half, placing arresters on the same pole with the transformers has still further reduced the trouble by one-third, and by further improvements in protection the troubles may be again decreased one-half, making a total of one-twelfth the present troubles. Since the total trouble was originally small, a reduction to one-twelfth makes the effects of lightning quite negligible.

The new conception of the danger from surges is furnished by the data which show that where a terminal board is exposed in such a way as to allow a lightning discharge to take place through the case, the transformer is not protected but actually damaged. Short circuits at the terminal of a transformer cut off the coils from the heating effect of the current. What, then, could damage the transformer coils but a surge? Mr. Roper's results show that one-third more transformers were damaged where the terminals were exposed than where they were not exposed. These data have important significance.

Summarizing the situation, all the information collected to date would impose the following practise for the protection against lightning:

First: Have no exposed terminal boards. By that I mean the discontinuance of the practise of using a terminal board as any sort of protection for the transformer.

Second: Place the arrester on the same pole with the transformer. The objection brought up by one of the speakers that different grounds should be used is pertinent, but that has nothing to do with placing the lightning arresters on the same pole with the transformer, as two separate grounds can still be used where desired, and in every case it seems to me desirable to have a gap between the lightning arrester ground, and the ground on the secondary of the transformer.

Third: Use an arrester with good protective qualities. These practical investigations Mr. Roper has made have given us information on the nature of the lightning strokes, that is to say, the percentage of low frequency strokes to high frequency strokes, and steepness of the wave front, and therefore we are able today to choose the factors in a lightning arrester to better advantage than ever before.

Fourth: Ground the transformer case to the ground terminal of the arrester, through a gap if desired. Although many engineers differ with this conclusion, my own tests have shown that connecting the case to the ground terminal of the arrester gives a valuable improvement in the protection, in that it makes the protective element of the arrester more nearly independent of the resistance of the earth connection.

There are many places where it is absolutely impossible to get a good earth connection. It has been pointed out that the object in protection is not necessarily to reduce the lightning potential to ground potential, but to prevent a great difference of potential from the primary to the secondary and case. If the lightning arrester is connected from the primary to the case, and through a gap to the secondary, then it is possible to have the transformer, say, at 200,000 volts above ground potential, with only a difference of potential from the primary to the secondary and case of about 6000 or 8000 volts. This point of connecting the lightning arrester to the case is, I believe, the solution of the problem presented by high-resistance earth connections. Furthermore, it eliminates the inductance of 30 ft. of line from the transformer to the ground. It has been demonstrated in practise, by many years of experience, that a short length of line, even the distance from the transformer to the next pole, introduces in the arrester circuit sufficient inductance to greatly decrease the protection of the transformer. Therefore, it is reasonable to conclude that the 30-ft. length from the transformer to ground is also objectionable.

H. B. Alverson: Mr. Roper's paper has pointed out very definitely the troubles occurring with the transformers and the fuses. It is very evident that the transformer ought not to be a lightning arrester, and this one point would argue for a change of the matter of terminal boards in the transformers.

The question of lightning arresters on the same pole with transformers is a very difficult one in city work, where you have joint line construction, and you are compelled to use the same poles with, perhaps, two other telephone companies. The use of a number of lightning arresters on a circuit is bad practise, in case of trouble, when you have to look up the source of trouble. A limited number of lightning arresters properly placed will do as much good, and trouble is easier to locate, than with a greater number of lightning arresters connected with your distributing transformers.

As to the question of fuse box, I believe with Mr. Roper, that that question should be considered entirely separate from that of transformers. The question of the fuse box can be better determined by the nature of the work outside, and the method of locating them on the poles.

W. L. Granger: Nearly two years ago we undertook to standardize our transformer connections, that is, we removed the terminal boards. Of course, the conditions in Detroit are such that it leaves us with a pretty clear course, in other words, there are two entirely independent systems, one operating at 4600 volts and the other one at 2300 volts. We find that we are getting very good results from the change.

In regard to Mr. Lincoln's remarks relative to the proper dimensions of the terminal block at the oil level, it appeared from our experience that the dimensions were of comparatively little

consequence; that is to say, if you had a transformer located in the manufacturing district where there was a lot of smoke and coal soot, the transformer in time is bound to breathe in more or less of this soot and smoke. We found in the summer time that the oil would evaporate and there would be some moisture on top of the block, and this soot and smoke would go right in on it, and it did not seem to make much difference, after a time, what distance you might have between these terminals on the primary side of the transformer. In other words, we found the transformers would break down across the block, due to losses on the lines, in the winter time, even, when there was no lightning, so that we are taking the connection boards out entirely and ordering our new transformers without the blocks at all.

In regard to lightning arresters, I quite agree with Mr. Roper on his proposition of furnishing a lightning arrester for each transformer. It appears, after some observation on my part and some little experience, that this will probably solve the problem.

As to the matter of lightning arresters that break down in service, causing arcing grounds on such a line, last summer I inserted in the line side of the lightning arrester unit a fuse which was a piece of No. 18 copper wire inside a glass tube. It was a very inexpensive affair, placed away from the lightning arrester itself, so that the terminal leading from the fuse into the box is a flexible piece of wire. We have had fairly good success with this device, so that what we are doing this year is to put in these fuses in all of our multi-gap arresters.

W. J. Wooldridge: There are three principal points to which we must look in order to insure reliability of transformers. Two of these points have been touched on, the first being the design, which includes the proper proportioning of insulation and arrangement of cords and connections, etc.; the second being the actual manufacture; and the third being the insulation and protection of installed apparatus.

It is a little out of line, perhaps, with what has been discussed, but I would like to say a word on a certain point, and that is the actual point of manufacture.

It is very essential, of course, that the insulation should be kept intact. The engineer must allow a certain margin of safety when he figures on the amount of insulation to be put in, and part of that margin of safety is to be allowed for possible accidents in the installation; but a great deal depends upon the careful handling of the insulation by the workmen. The workmen, in order to be taught to properly handle the insulation, cannot be successfully reprimanded or coerced, they must be coaxed and trained into understanding the full value of insulation; and in order to put the workmen into a proper frame of mind, the idea of safety first has to be thoroughly carried out. The workman must be made to understand that he, too, is being looked after in the same way that he must look after the material.

D. W. Roper: Mr. Moody in opening the discussion brought out the point that co-operation such as is shown in this paper, was desirable. We sometimes have the same difficulty in getting the co-operation of some of our customers—they expect us to relieve them of their troubles without knowing anything about them, and it is only after being properly informed of the troubles which occur that we can take steps to remedy or eliminate them.

On the question of connection boards, on which there was quite a little discussion, the conclusions as reached in the paper were criticised, and it was suggested that an improved design of connection board would have shown quite different results. That is very true, but in the case of an operating company, which has no use for a connection board, it does not appeal very strongly to them to experiment in trying to eliminate the difficulties in the connection board, if they can as well eliminate the connection board itself. In Chicago the present practise in purchasing transformers is to remove them before they are placed in service, and in addition, the transformers which come into the storeroom due to changes, such as increase in capacity, or to removals, or changes in location, or other contingencies of that kind, have their connection boards removed before again going out on the line.

The point was raised that Tables IV and V referred to transformers of quite different ages. That is very true. The ages of the various transformers were quite different, and the difficulty was recognized of properly allowing for the difference in age in making up the curves which are shown in these tables. However, if such an allowance had been made it would have served to accentuate the differences shown in the table.

The point was raised of the difficulty of installing lightning arresters on the same pole with transformers on account of the necessity of having a separate ground for the lightning arrester and the transformer secondary. That is a point which comes up frequently, but we have settled it for our purpose by installing the lightning arrester ground on the same pole with the transformer, and installing the secondary ground on a different pole. In most of the installations the transformer secondary serves a number of customers, so we can just as well put the secondary ground on the adjacent pole. Where necessary we string in an additional span of the secondary neutral wire for the purpose of removing the secondary ground to the next pole, and getting it away from the lightning arrester ground.

The question was raised of the additional troubles which would be experienced with the large number of lightning arrester. Our experience with several types of lightning arresters is that, on the whole, the lightning arresters of the present day give comparatively few interruptions to service, and that they are almost as reliable, as far as freedom from interruption of the service is concerned, as the transformers themselves. These remarks do not refer at all to their value as protective devices, but refer to their vulnerablity, as you might call it, or their danger as a source of interruption.

A point was also raised about the grounding of transformer cases. This matter was not mentioned in the paper, not because we have no installations of that kind, but because they have not been in service long enough to have given us any different experiences to report. We have about six hundred transformers whose cases are grounded on three different circuits, and we are trying to keep our records, so we will have some practical experience along that line.

The statement was made that there was some difficulty in getting proper grounds where joint pole line construction was used. A large proportion of the distribution in Chicago is on pole lines jointly owned. The worst that can happen in such a case is that the telephone company may locate a ground for their aerial cable sheath on the pole that you afterwards select as a transformer pole, and the solution of that difficulty is to pay them to remove it to the next pole.

The point was raised that an arrester on each transformer was not necessary. That is true; it is merely a question of the quality of service which the company desires to supply to its customers. With a small number of lightning arresters they can give one grade of service, and with a larger number of arresters they can give a little higher grade. If the smaller number of arresters is sufficient to supply the demand in your particular city there is no object in incurring the additional expense of the larger number of arresters.

Discussion on "Inherent Voltage Relations in Y and Delta Connections" (Sorensen and Newton) and "Harmonic Voltages in Currents in Y and Delta-Connected Transformers," (Clinker), Pittsfield, Mass., May 28, 1914. (See Proceedings for May and June, 1914.

(Subject to final revision for the Transactions.)

Waldo V. Lyon (by letter): The interesting fact that Mr. Clinker notes in regard to the possibility of a third-harmonic voltage existing between the lines of a three-phase circuit was observed by the writer some time since, and was used as the basis of one of the problems in a collection* recently published by him. These third-harmonic components in the line voltages are equal but differ in phase by 120 degrees (third-harmonic scale) so that the circuit should respond to their influence in the same way that it would if sinusoidal voltages of three times the fundamental frequency were impressed upon it. This might produce serious results especially in transmission lines, if the harmonics were of sufficient magnitude. This phase difference in the third harmonic makes the resulting three-phase voltages dissimilar as Mr. Clinker points out. Their effective values, however, are equal.

In a three-phase generator the voltage reduction factor for the third harmonic, assuming a phase spread of one-third and a coil pitch of one, is about 64 per cent. On the other hand, in a two-phase generator this reduction factor, assuming a phase spread of one-half and a coil pitch of one, is about 30 per cent. The corresponding reduction factors for the fundamental in the two-phase and three-phase generators are 96 per cent and 90 per cent. These factors are for a winding that is completely distributed Thus, for the same flux distribution and the same phase voltage, the third harmonic component would only be $\frac{30 \times 96}{90 \times 64}$ or, one-half as great in a two-phase generator as in a three-phase generator.

A. E. Kennelly and Harold Pender (by letter): In connection with Mr. Clinker's observation on a rise of pressure of 37 or 33 per cent in different cases, attributable to partial resonance, with triple harmonic frequency, we may mention that on an artificial line at the Massachusetts Institute of Technology, built to represent a three-phase aerial three-wire 500,000 circular-mil conductor system 240 miles long, a voltage rise of 20:1 was observed experimentally by us at a frequency af 189~ which is substantially a triple harmonic frequency to the standard frequency of 60 ~. That is, when this length of artificial line was operated with 50 volts at the generating end and with 189~, the voltage at the distant free end reached 1000 volts, and this result checks very well with the theoretically deduced value.

*"Problems in Alternating Current Machinery," Problem 10, p. 127.

The application of the above-mentioned result to voltage regulation on a fairly long transmission line will be evident in the case of a voltage containing a high harmonic to which the line may happen to be a quarter wave length. For example, a line 240 miles long would be roughly quarter wave length to a third harmonic in a 60-cycle generator voltage wave. A five per cent harmonic at the generator would produce a 20 × 5 equals 100 per cent third harmonic at the receiving end at no load and so might produce, in combination with the fundamental, a peak voltage of twice the peak voltage at the generator.

F. W. Peek, Jr.: I was much interested, in reading these papers, to see the number of times the "third harmonic" was referred to or discussed. There are a great many phenomena existing in engineering which are not generally observed until something happens to make them annoying in practical work.

In certain transformer connections the third harmonic, inherently in the magnetizing current with applied sine wave voltage, is the cause of abnormal stress to ground. This is especially so with long lines of high capacity.

If Y-connected auto-transformers, with their neutral grounded as the only ground, are used to step up the generator voltage, *abnormal potentials to ground* may result. These excess voltages are *not indicated by a voltmeter but by "static" on leads*, excessive losses, or *by a spark gap* connected between one line and ground. The reason that a voltmeter does not indicate this high voltage is that the effective value of the voltage is not greatly changed, but only the maximum value of the wave is increased, and this is indicated by a spark gap, or stress between the insulation and ground. The cause of the voltage distortion is as follows:

When a sine wave e.m.f. is applied to a transformer, the resulting magnetizing current wave cannot be a sine wave but must follow the changing permeability of the iron,—this current wave contains the third harmonic. The current and voltage waves can never be the same, but, if the magnetizing current wave is a sine wave, the voltage wave must then contain a third harmonic, or *vice versa*. Hence, if anything prevents or suppresses the third harmonic in the magnetizing current the applied sine wave of voltage must then become distorted.

In a three-phase transformer the currents are 120 deg. apart for the fundamental frequency, or 3 × 120 or 360 deg. apart for the third harmonic; that is, in phase. Thus for Y-connected auto-transformers the triple frequency magnetizing currents to neutral must be in phase. The sum of the three currents flowing to a point must be zero. Hence, as the third harmonic magnetizing currents are all in phase, they must all be zero to satisfy these conditions; that is, they must be suppressed. This means that the current wave approaches a sine and that therefore the voltage to neutral cannot be a sine wave but must be peaked, or contain the third harmonic, which appears as voltage rise to neutral and causes extra iron and insulation loss. The distortion does not appear in the voltage between lines because

the distortion between one line and neutral is cancelled by that of the other two lines. The voltage distortion may be eliminated by supplying a path for the triple-frequency exciting current; that is, in this case, by connecting the transformer neutral to the generator neutral. This supplies a single-phase circuit for the triple frequency through the line and generator. A current of the proper phase relation flows and the distortion disappears.

If, before this connection is made to the generator, the transformer is connected to a transmission line, a path is supplied for triple frequency current through the capacity from line to ground. This capacity offers three single-phase circuits. A triple-frequency current thus flows but it has not the proper phase relation for the triple-frequency excitation current, and instead of eliminating the voltage distortion it greatly increases it. A double peak may occur in the fundamental voltage wave which causes an increased iron loss. This distortion, however, also generally disappears when the auto-transformer neutral is connected to the generator neutral. Without this inter-connection the distortion is greater in the case where the transformer is connected to a capacity. The peak of the wave may be several times normal. The effect of capacity is well brought out by Mr. Blume. There are other ways of supplying this third harmonic current; for instance, by a closed delta in the transformer.

If a grounded-Y auto-transformer is used to step up the voltage of a generator with non-grounded neutral, and at the far end of the line is a transformer with grounded Y on the line side and delta on the low side, triple-frequency current is supplied from this transformer to the auto-transformer through the ground by the three single-phase paths. These ground currents may cause telephone troubles; if the transformer at the far end is small compared to the auto-transformer, the triple-frequency exciting current may overload it and cause it to burn out.

The third harmonic is thus a "constant current" effect, that is, the voltage drops when triple-frequency current with the *proper phase relation flows* through a low-resistance path. If the circuit has high resistance the voltage becomes high.

There may also be a third harmonic in the generator wave, due to the relation of the windings, which has a "constant voltage" effect and which may produce very *heavy triple-frequency currents* with improper connection, or when a short circuit path is afforded for these currents. Precautions are thus necessary where several generators are connected in parallel and the neutrals grounded. If all of the generators are of identical design, very large triple-frequency excitation currents may flow unless the field excitation is the same on all of the generators. If the generators are not of identical design, dangerously large triple frequency currents may result. When a number of generators are operated in parallel and the voltage is stepped up by auto-transformers, it is often practicable to ground only one generator

at a time and to connect to this ground all of the transformer neutrals.

Whenever auto-transformers are used it is necessary to investigate the possibilities of trouble for the particular case under consideration. Their use is generally not to be recommended.

There are other transformer connections which may cause high triple frequency voltages, as an instance, Y-Y.

Louis F. Blume: In connection with Mr. Clinker's paper, I wish to point out that the Scott-connected transformer should not be held responsible for the third harmonic which appears in the three-phase system. If the Scott-connected transformer had been omitted, and the generator connected in "T", the third harmonic would have appeared in the line just as described.

F. C. Green: Reference is made in the paper by Messrs. Sorensen and Newton to some experiences that were had in a western system. I happened to be connected with the installation of that system, and made some tests on triple-frequency effects related by the authors in their paper.

For the tests, the bank of compensators was excited at 60,000 volts and stepped this voltage down to 50,000 volts. The neutral was not grounded except the slight grounding effect that resulted when measuring potential between neutral and ground by means of a potential transformer. Tests were made with the auto-transformers open on the 50,000-volt side and also with them feeding into the 50,000-volt system, there being practically no difference in the measured values for the different conditions. With 60,000 volts impressed, the voltage between neutral and 60,000-volt terminals was 42,000 volts; between neutral and ground, 18,600 volts; between 60,000-volt terminals and ground 36,600 volts. All measurements were made with potential transformer. No tests were made under the condition that had caused trouble, namely, with only the auto-transformer neutral grounded in the 50,000-volt system; the reason being fear of damage to the line.

Under the system of connections that was planned to be used there, the grounding of the neutral would not have caused any excessive voltages. On occasions of line disturbances, it sometimes happened that all other grounded neutrals in the system were disconnected, leaving only the auto-transformers' neutrals grounded.

Mr. Clinker mentions in his paper an instance where trouble due to triple-frequency effect was relieved by grounding the auto-transformer neutral. In the system discussed above, it was necessary to unground the neutral to prevent damage. The theory for this case is given in Mr. Blume's paper.

Triple-frequency effects have been well covered and there is now no reason for experiencing any more trouble from them. Until some new phenomena develop in operation, due to their existence, it seems that efforts should be directed to the solution of other and more vital features of the subject under discussion.

C. L. Fortescue: In connection with Mr. Clinker's paper, if I am not mistaken, in previous discussions on a paper by Mr. Frank this peculiarity of the Scott connection has been pointed out. The third harmonics which exists in the two-phase generator are transformed, so that they appear in the three-phase circuit in three-phase relation after transformation. This will be found to be true also in any transformation or any generation, whether produced in a generator or transformed in a transformer in which there is dissymmetry in the phases. The triple harmonic effects present will appear in three-phase relation causing differences in the wave forms of the voltages between the mains as a result of dissymmetry in the windings of the transformers or in phases of the generator.

P. M. Lincoln: This observation brought out in Mr. Clinker's paper is of interest to me, because in studing the wave forms of the Niagara Falls generator, which was installed about nineteen years ago, I observed the same thing. The Niagara generators had slightly flat-topped waves, similar to those Mr. Clinker has shown. If you take a two-phase generator, such as we had at Niagara, and get three phases from it by the Scott connection, you will have one of the phases going through the transformation with the wave form unchanged, the same on the three-phase as on the two-phase side. That will be what we may call the main phase. Of the other two, one of them will be a peaked wave and the deformation will be to one side of the neutral axis, say on the right hand side. You will find the other phase will be exactly similar, except that the peak will be formed on the left hand side. If you start with a peak wave, you will find when you get through to the three-phase side, you will have one peak wave and two flat-top waves, distorted, one to the right and the other to the left. It is not a new observation, by any means, and has been known for a great many years.

J. M. Weed: I wish only to raise a point of theoretical interest in connection with Mr. Clinker's paper. Mr. Clinker has attributed the third harmonic component in exciting currents to the effect of hysteresis. To see that this is not correct, it is only necessary to consider that hysteresis constitutes an energy loss in the iron, and that with a sinusoidal voltage applied, energy can be supplied only by current of the same frequency as the voltage; *i.e.*, by a fundamental component of the exciting current. The triple harmonic and all higher harmonic components of the exciting current are not due to hysteresis, but to the permeability characteristics of the iron; *i.e.*, to variations in permeability with changes in the magnetic density.

D. C. Jackson: As Dr. Kennelly referred to the artificial line at the Massachusetts Institute of Technology, it will be interesting to add that it is a line made up of No. 12 B. & S. gage wire that has resistance, self-inductance and capacity which causes it to represent substantially 750 miles of length of line, 500,000-circular-mil conductor, spaced at 8 feet, center to center.

That is about the line which would be used for the transmission of power from the Falls of the Nile to South Africa.

The one-third length which Dr. Kennelly used in his experiments was a part of that line. The reason for the line being built of the No. 12 B. & S. gage wire was to make it practicable to use ordinary portable ampere-meters, voltmeters, or wattmeters in connection with it, without interfering seriously with its normal performance. As far as tests have gone that seems to be what can be done, and makes it very convenient. One can find out the operating characteristics of the line by using portable amperemeters, voltmeters or wattmeters, in the ordinary fashion, apparently, and do it in relatively little time. I think, in the case of the Schenectady line, it is necessary to have special instruments to be used with the experimental line, it being of small wire of relatively high resistance.

This line at the Massachusetts Institute of Technology when operated at 60 cycles, open circuit, pure sine wave, gives a rise of voltage of about 9 to 1 in the full length, that is, 120 volts impressed at the generator end gives something over 1000 volts at the receiver end, open circuit. Of course, a very small load on the line changes that promptly, as the formula shows.

The line responds closely to what the formula indicates, although it is what is called a lumpy line.

DISCUSSION ON "INFLUENCE OF TRANSFORMER CONNECTIONS ON OPERATION" (BLUME), "A STUDY OF SOME THREE-PHASE SYSTEMS" (FORTESCUE) AND "EXPERIENCE OF THE PACIFIC GAS & ELECTRIC CO. WITH THE GROUNDED NEUTRAL" (JOLLYMAN, DOWNING AND BAUM), PITTSFIELD, MASS., MAY 29, 1914. (SEE PROCEEDINGS FOR MAY, 1914.)

(Subject to final revision for the Transactions.)

Guido Semenza (by letter): Italy is one of the countries of Europe which has largely developed the electric transmission of power from hydroelectric installation. In fact there are in Italy, the area of which is about double that of the State of New York, more than 2400 hydroelectric power houses, nearly all of them provided with transmission and distribution lines.

It may be of some interest to you to know the general opinion in this country on the problem under discussion.

The writer recently questioned the engineers of several Italian plants in order to have their opinion: The power of these plants varies from a few thousand kilowatts to 40,000 kw., with transmission by overhead lines at voltages varying from 6000 to 88,000 volts and by underground lines up to 25,000 volts.

First, concerning overhead high-tension transmission:

a. The great majority of the systems are delta-connected, consequently insulated from the ground.

b. A few are Y-connected with a spark gap (horn-arrester) between the neutral points and the ground.

c. A few have a real grounded neutral point across a resistance of some kind.

d. Only two to my knowledge have the neutral point grounded without resistance. (Which I will call a short ground).

Second. Concerning underground high-tension lines: No system of this kind is known with grounded neutral, either with or without resistances.

Third. Concerning low-tension distributions: All sorts of arrangements are to be found, insulated delta, grounded Y, four-wire three-phase with grounded neutral, etc.

It must be noted that the first three-phase transmission plants constructed in Italy were planned with delta insulated connection, and their operation having proved satisfactory from the beginning, the same arrangement has been generally adopted all over the country.

Only later, in some installations in which a number of disturbances were noticed, as a trial, the neutral was grounded both in the power house and at some extreme point of the distribution; in some cases the practise proved to be good, as some of the disturbances were eliminated, while in other instances the remedy had a contrary effect.

For instance, on Subiaco-Roma line, where current is generated directly by alternators at 33,000 volts, the maker of the alternators imposed a grounded netural; but the moment an insulator was punctured the gradient of tension was so steep that it was

dangerous to walk about in the power house, the current passing through the ground not being always sufficient to trip the circuit-breaker.

In a general way, very serious disturbances were caused in telephone and telegraph circuits.

Among the large systems only that of the Societa Contiper Imprese Elettriche has a short grounded neutral of 50,000 and 25,000-volt overhead lines. This is one of the systems which is improved with the grounding; but a long period of disturbances on telephone lines was experienced. At last it was found that the principal cause of these was the third harmonic, due to over-saturated transformer.

The plant of the Municipality of Milan at 60,000 volts has the neutral point grounded through a water jet discharger.

The operation is good, but on both these systems interruptions of service are more frequent when compared with other analogous plants delta-connected.

Nearly all the other large systems are delta-connected, thus insulated from the ground. I recall the Milan Edison Company (15,000 volts), the Societa del Cellina ((30,000 volts) the Societa Adamello (72,000 volts), the Societa Meridonale di Elettricita (88,000 volts), the Societa Dinamo (50,000 volts), the Societa Imprese Elettriche Roma (60,000 volts), and many others.

Being personally in favor of the insulated delta arrangement, I will summarize here the reasons which are generally given in favor of this solution in my country:

1. With good circuit-breakers, a ground on line will always result in an interruption of the other line. Although keeping a line in service, with a ground on it, is not very frequent, it has sometimes occurred without giving any trouble.

2. The grounding through a resistance is an immediate solution which presents the disadvantages of both insulated and grounded systems. In fact, the disadvantage of the insulated system is said to be that full delta tension is put on an insulator when a line is grounded; but the resistance grounded neutral, when the accidental ground has a low resistance, so that the current is high, can give such a drop on a neutral connection that the tension on the insulators may rise quite near to the full delta value.

3. Ground connection is never a sure device. Moreover, a ground is effective only locally, but not at any distance. Therefore, only one ground in a large system is not considered sufficient.

4. Short grounded neutrals are apt to disturb all low current circuits. (Telegraph, telephone, signaling).

5. The practise in Italy is to over-insulate lines. It is considered that money spent in using larger insulators is well spent. So the advantage of grounded neutral in cheapening the cost of lines is not of great value here.

6. One of the most serious disturbances on long distance transmissions is the traveling surges caused by atmospheric

influence. It has not yet demonstrated that the grounded neutral has any beneficial influence on the accidents caused by such disturbances.

7. It is said that a neutral grounded prevents the accumulation of static charges. In many Italian systems this accumulation is prevented by water jet dischargers, acting on the busbars or on the line wires.

Concluding, I do not see many reasons for supporting the grounding of a neutral point, while I see many advantages for not doing it. I am persuaded that by using good insulation and good terminal protection, the insulated system affords all conditions for good and regular operation.

F. F. Brand: With reference to one of the points Mr. Semenza mentions, that is, with the grounded Y connections, serious disturbance was found to occur in telephone and telegraph lines, I would state that this disturbance can be considered as from two causes, one is current and one is voltage interference. Current interference can only occur where the current flowing in the lines is in the same direction in all the lines at the same instant, that is to say, there must be a current returning through the earth. In order to get a return current through the earth, it is necessary that there should be unbalanced current in the line, a triple harmonic current flowing through the earth.

In Europe it is common practise to use Y-Y-connected transformers. If the transformers are shell-type construction, there will be a return current flowing through the neutral, and they will get triple harmonic current flowing in the lines at the same instant, but if these machines are core-type there will be no appreciable flow of current to the neutral, due to the fact that there is practically no triple harmonic voltage between line and neutral in the core type transformer.

With reference to the interference of telephone lines, and the voltage disturbance, that is, I think, not very greatly different in the Y and delta connections.

W. W. Lewis: There are in North America, according to a statement issued recently by the *Electrical World*, (issue of April 25, 1914), 35 transmission systems operating at 70,000 volts and over, and in the remainder of the world 19 such systems. The following tabulation shows the division of these systems into Y and Delta:

	Y	Delta	Not Given	Total	Grounded Neut.
North America	19	14	2	35	18
Remainder of the World	10	6	3	19	6
	29	20	5	54	24

From the above it will be seen that of the forty-nine systems on which data are given, 29, or about 60 per cent, are Y connected, and 24, or about 50 per cent, have grounded neutral.

In North America, however, practically all the Y-connected systems are grounded, and about 55 per cent of the total number of systems.

These figures show a remarkably close division of opinion among operating engineers as to the relative merits of grounded Y and isolated delta, with the preponderance slightly in favor of the grounded Y in North America, at least. The following tabulation shows the number of systems started up each year, beginning with 1901, when the first one was put into operation:

Year	Number
1901	1
1906	2
1907	1
1908	0
1909	3
1910	8
1911	5
1912	6
1913	7
1914	13
1915	5
	51
Not given	3
	54

It will be noted that only four of these systems were installed prior to 1909. Counting the years 1914 and 1915, when some of the systems will be put into operation, practically the total development of high-tension transmission has taken place in about seven years. It is small wonder then that opinion should be divided as to the best method of connection, and that practical operating men are solving the problem by the method of experiment, which is after all the only conclusive method.

In the present discussion the writer has selected a half-dozen typical systems, three of which are connected isolated-delta and three grounded Y, and will briefly discuss certain points in their operating experience.

First, Great Western Power Company. (Isolated Delta).

This system is the only one of importance operating isolated delta in the State of California. It runs from Big Bend to Oakland, and is about 154 miles long. At no point is the altitude over 500 feet.

The operating voltage is 100,000 volts. Operation was begun in 1909. There are two circuits on the same towers, the conductors being arranged vertically. There is one overhead ground wire at the middle of the towers.

Lightning is very infrequent, (about twice a year) and no

trouble is caused by it. Short-circuits and arcing grounds cause some trouble (about once in two or three months). Arcing grounds destroy the telephone communication, break down insulators, and frequently burn off the line wire. Short circuits also necessitate shutting down the system.

At Oakland, the Great Western System is connected by delta-delta transformers to the grounded-Y system of the Pacific Gas & Electric Company. Some of the disturbances originating on the latter system, no doubt, are felt on the former system.

Second. Colorado Power Company. (Isolated Delta).

This system consists of two parts, the Shoshone-Denver line, one hundred and fifty-three miles long, and the Boulder-Denver line, twenty-eight miles long. The two lines are capable of being tied together at the Denver substation. The operating voltage is 100,000 volts. The system has been in operation since 1909. The transformers at all points are delta-connected on the high side, except at Boulder, where they are isolated-Y. The conductors are placed horizontally. There is one ground wire at the middle of the towers.

The Shoshone-Denver line runs over some of the roughest country in the United States, and at one place reaches an altitude of 13,500 feet. Lightning is severe at certain times of the year, and wind velocities of 150 miles per hour are at times recorded.

An analysis of the disturbances of this system in 1912 shows 42 per cent due to wind, 30 per cent due to lightning, and the balance due to construction failures, extraordinary causes and unknown causes.

The greatest part of the trouble is due to short circuits, caused by wires swinging together during wind storms, and by arcing grounds, due to the lines swinging against the towers or ground wire. A shut-down usually results from either a short circuit or an arcing ground.

It has been found impossible to operate the long Shoshone-Denver line with one conductor dead grounded, due to the increase in corona loss and charging current.

The short Boulder-Denver line, however, has been operated for hours with a dead ground on one line.

However, a ground on the line, either arcing or dead, interferes with telephone communication, and this usually necessitates a shut-down.

Third. Au Sable Electric Company. (Isolated Delta).

The main line of this system operates at 140,000 volts, and extends from Au Sable to Owosso, in eastern Michigan, a distance of about 160 miles. The system consists of a single circuit, the conductors being arranged two on one side and one on the other side of the tower. There is no ground wire. Operation was begun in 1912.

The lightning is very severe. The country is open and the lines are much exposed. Practically all the storms which cause interruption of service occur during the season from May to

September. Lightning causes simultaneous arc-overs from two or three lines to ground over insulators or bushings, thus resulting in phase short circuits.

Fourth. Sierra & San Francisco Power Co. (*grounded Y*):

This system is located in California, in much the same kind of territory as the Great Western Power Company system. The line extends from Stanislaus to San Francisco, a distance of about 135 miles. The operating voltage is 104,000, the maximum altitude about 1000 feet. Operation was begun in 1910. The system consists of two circuits on the same towers, conductors arranged vertically, no ground wire. The two lines are connected in parallel on the low-voltage side. The neutrals on both ends of the line are dead grounded.

Short circuits by leaky insulators, large birds, etc., occur on an average of about once a month.

Short circuits are usually taken care of by separating the lines on the low-voltage side and cutting out the affected line. Grounds rarely develop into short circuits between phases, but the line wire or the insulators usually burn off. There is practically no lightning trouble on this system.

Fifth. Yadkin River Power Co. (*Grounded Y*).

This system is situated in North Carolina, and the main line runs from Blewett's Falls to Method, a distance of about 90 miles. The operating voltage is about 100,000 volts.

There are two circuits on steel towers, the conductors in a vertical plane, one ground wire at the middle of the towers. The neutral is dead grounded at the generating end only.

Lightning is extremely severe for several months in the year. Operation of the system was commenced in 1912, with isolated neutral; but this was changed after about a year to grounded neutral.

Grounds and short circuits are frequent. A device has been used to reduce trouble from short circuits. This consists of a relay in the neutral, which, when operated by ground current, throws a large resistance in series with the field of the generator exciter, thus momentarily reducing the voltage and allowing the short circuit to die out.

Sixth. Pennsylvania Water & Power Co. (*Grounded Y*)

This system is grounded through a resistance. The power is generated on the Susquehanna River, in Southern Pennsylvania, and transmitted at 70,000 volts to Baltimore, a distance of about 40 miles. There are two sets of towers, with two circuits per tower; conductors arranged vertically; one ground wire per tower. Operation was begun in 1910.

The lightning is severe in this district and short-circuits due to insulators flashing over are frequent. Interruptions have been greatly reduced by a device which short-circuits the line at the station through a fuse, thus allowing the arc over the insulator to become extinguished. This device is supplemented by another consisting of series line relays, which act on the

generator field, opening it momentarily and then closing it, the whole action taking place so rapidly that synchronous apparatus does not get out of step. With the assistance of these auxiliary devices, operation is said to be very satisfactory.

Conclusions. It will be seen from the above that neither the isolated-delta nor grounded Y systems are free from trouble.

The amount of trouble is governed largely by location, climate and mechanical details of line construction.

Two arguments which are frequently used in favor of the isolated-delta system are proved in practise to be fallacious:

First, that only voltage troubles need be expected. On the Colorado and Au Sable systems phase short-circuits are numerous.

Second. That a delta system can operate continuously in case of a dead ground on one line. This is only true for very short lines, as on long lines the charging current—due to the increased capacity and voltage—becomes excessive, likewise the corona loss. The telephone system is also invariably disturbed, so on this account operation usually must be discontinued.

On the other hand, the short-circuit troubles on the grounded *Y* system are very severe, and some auxiliary short circuiting and field destroying devices are almost essential to render satisfactory operation.

As far as operation is concerned, it seems that both systems have their advantages and defects, and that in selecting a system, the location and climatic conditions should be carefully considered.

V. M. Montsinger: About a year and a half ago, Dr. Steinmetz and Mr. Faccioli suggested to Mr. Blume and myself an investigation of the effect of electrostatic capacity and reactance on third harmonics in Y auto-transformers.

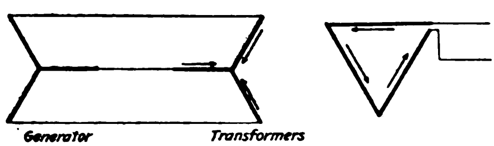


FIG. 1—DIAGRAMMATIC SKETCH OF GENERATOR AND TRANSFORMERS FOR MAKING THIRD-HARMONIC VOLTAGE TESTS. ARROWS SHOW DIRECTION OF TRIPLE-FREQUENCY VOLTS.

Some tests were made on small transformers connected as shown in Fig. 1 to determine to what extent the triple voltage was increased by electrostatic capacity supplied from condensers connected across the legs of the secondary windings. The transformers were excited from a Y-connected generator of several times the sum of the capacities of the transformers.

A rather peculiar phenomenon was found to take place, that

is, when the condensers were connected, the triple voltage, at a certain value of the core density, suddenly rose, almost in a straight line, to a value slightly over 200 per cent of the fundamental; but on increasing the core density, the triple voltage decreased almost as suddenly to approximately its normal value, corresponding to that particular density without capacity. This same phenomenon occurred also when the condensers were placed across the opening in the delta.

By connecting the transformers as shown in Fig. 1, we were able to differentiate the triple voltage from the fundamental and other higher harmonics, not multiples of the third, and to

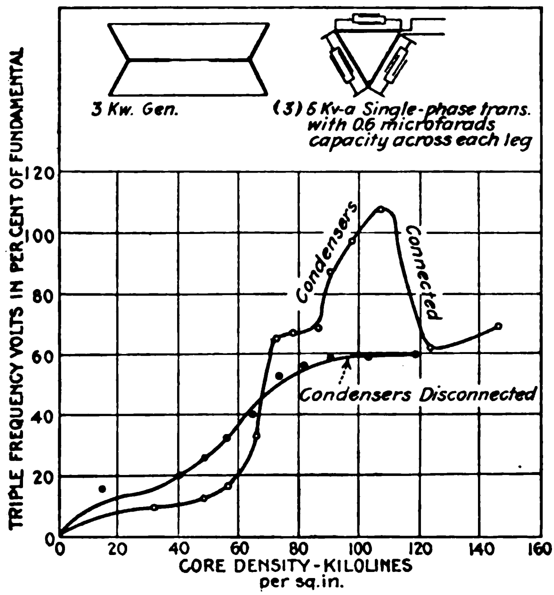


Fig. 2—Curves Showing Triple-Frequency Volts Observed Across Open Delta, With and Without Condensers Connected Across Delta Legs

determine the third harmonics in per cent of the fundamental voltage.

Fig. 2 shows the results of tests recently conducted with three 5-kv-a. core-type transformers connected with and without condensers, and excited by a 3 kw. generator as shown by the sketch in the upper part of the diagram.

Fig. 3 shows the same transformers and generator connections. The condensers in this case, however, were connected in an opening in one corner of the delta, and the voltage read across the condensers. In this case, as will be seen later, the condensers draw only a triple-frequency current.

For the case as given in Fig. 2, the condensers draw a complex current which is composed of the fundamental and of the triple frequency. The same condition would be true if the condensers were connected between the neutral point to the lines of the Y on the excited side of the transformer, which case represents the conditions existing with a transmission line of an isolated system connected to Y auto-transformers with the neutral point grounded.

The indications are that if we have the right conditions existing, that is, if the electrostatic capacity of a transmission line is of the proper value, and if the flux density of the transformers

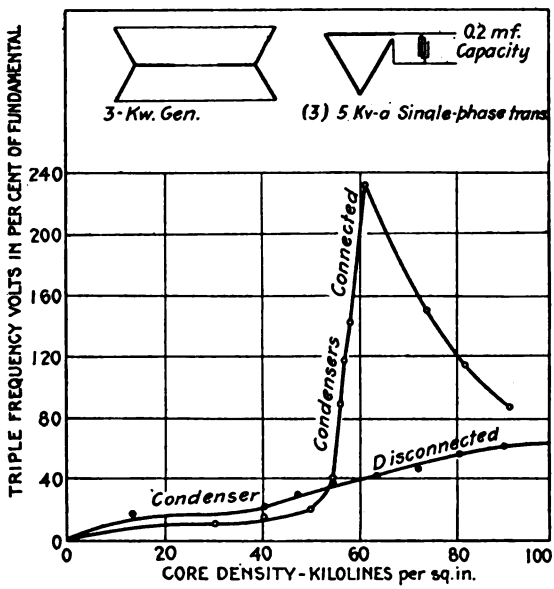


Fig. 3—Curves Showing Triple-Frequency Volts Observed Across Open Delta, With and Without Condensers Connected

is at the point to allow third harmonic intensification, there may be severe line disturbances which would cause strains on the line and transformer insulation.

With these transformers, excited by the small generator, as shown in Figs. 2 and 3, an increase or a decrease in the electrostatic capacity gave a smaller intensification, or peak value, of the triple-frequency volts, while with the larger generator, with practically the same transformers, the indications were that with a larger condenser capacity, the peak values would have been still larger, but on account of the condensers, being of low voltage, and arcing over, higher values could not be recorded. However, since the iron in transformers is generally worked

not far below the saturation point, the third-harmonic potential peaks can never exceed, to any great extent, three times normal potential.

Fig. 4 shows the results of tests made under the same conditions as those given in Fig. 3, except that a 150-kv-a. instead of a 3-kv-a. generator was used, and that 0.6 mf. instead of 0.2 mf. capacity was connected across the opening in the delta. It will be noted that with the larger condenser capacity, the maximum triple frequency intensification occurs at a lower core density and that after the first rise and fall, a second and third rise occur. At these peaks, after the first, a marked humming sound in the transformers indicated that the frequency was

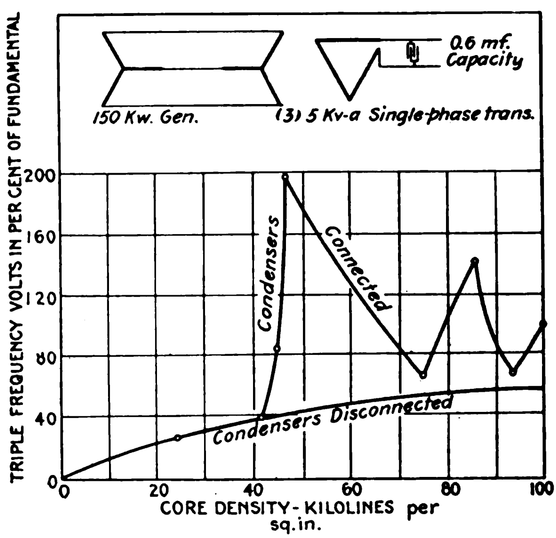


FIG. 4—CURVES SHOWING TRIPLE-FREQUENCY VOLTS OBSERVED ACROSS OPEN DELTA, WITH AND WITHOUT CONDENSERS CONNECTED

higher than a triple harmonic—probably multiples thereof. The lower curve, A, shows the approximate minimum triple voltage existing in any group of three single-phase core type transformers or auto-transformers connected so that a third-harmonic circulating current cannot flow.

This curve, together with the current circulating in the delta when closed, is given in Fig. 5 for different core densities. Also similar voltage and current curves are given for a three-phase, 15-kv-a. core type transformer.

The curves in Fig. 6 show the effect of electrostatic capacity on the triple frequency volts of a three-phase core-type transformer. Although a fairly large condenser capacity was placed

across the delta legs and across the opening in the delta, practically no increase was obtained in the third-harmonic volts.

Incidentally, I might mention here that this method of connecting three single-phase transformers was first proposed, I

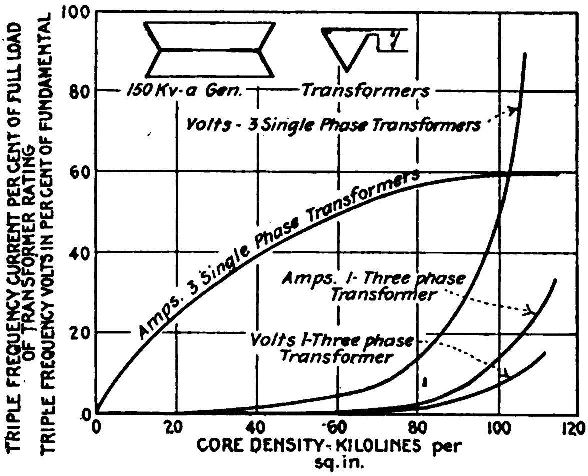


FIG. 5—CURVES SHOWING TRIPLE-FREQUENCY VOLTS IN OPENED, AND AMPERES IN CLOSED DELTA OF THREE 5-KV-A. SINGLE-PHASE TRANSFORMERS AND OF ONE 15-KV-A. THREE-PHASE CORE-TYPE TRANSFORMER

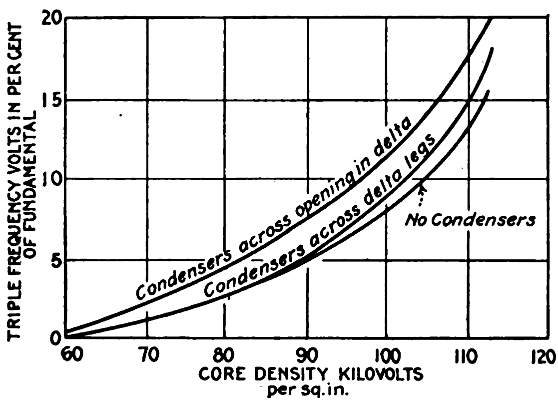


FIG. 6—CURVES SHOWING EFFECT OF ELECTROSTATIC CAPACITY ON TRIPLE VOLTAGE OF THREE-PHASE 15-KV-A. CORE-TYPE TRANSFORMERS CONNECTED Y-DELTA, EXCITED BY 150-KV-A. GENERATOR. 1.0 MF. CAPACITY ACROSS OPENING IN DELTA AND ACROSS EACH DELTA LEG

believe, by Mr. Spinelli, an Italian engineer, for transforming from three-phase to single-phase triple-frequency power under balanced conditions, by placing a load across the opening in the delta.

The results of tests made with three single-phase transformers operating at a flux density of 97 kilolines per sq. in., are shown in Fig. 7. The conditions were perfectly balanced, but the disadvantages found were: first, that the transformer efficiency was comparatively low; second, that the power factor was very poor, and third, that there was practically no voltage regulation whatever. The maximum efficiency of output divided by input was about 80 per cent, while that of the output divided by the transformer rating was only about 17 per cent. The maximum power factor was about 0.27. However, Mr. Taylor, an English engineer,* proposes a means of improving the regulation although the efficiency and power factor are still low.

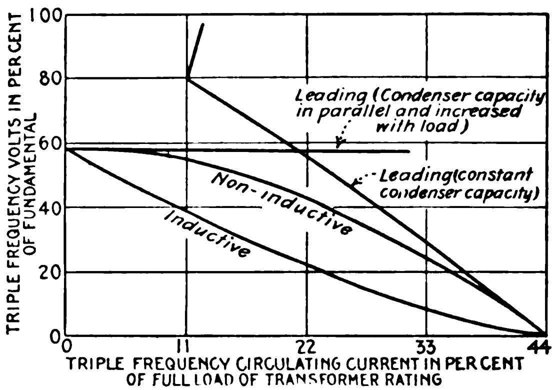


FIG. 7—CURVES SHOWING VOLTAGE REGULATION FOR LEADING, LAGGING AND NON-INDUCTIVE LOADS ACROSS OPEN DELTA OF THREE 5-KV-A. SINGLE-PHASE Y-DELTA CONNECTED TRANSFORMERS, OPERATING AT A CORE DENSITY OF 97 KILOLINES

The following illustrations show the shapes of the current and voltage waves at different points on these curves.

Fig. 8 was taken at a density of 65 kilolines, and shows the waves of the voltage across the opening in the delta and across the lines of the Y side. No condensers were connected.

Fig. 9 shows the voltage across the leg of the delta and across the opening in the delta with condensers across the delta legs. Density 100 kilolines.

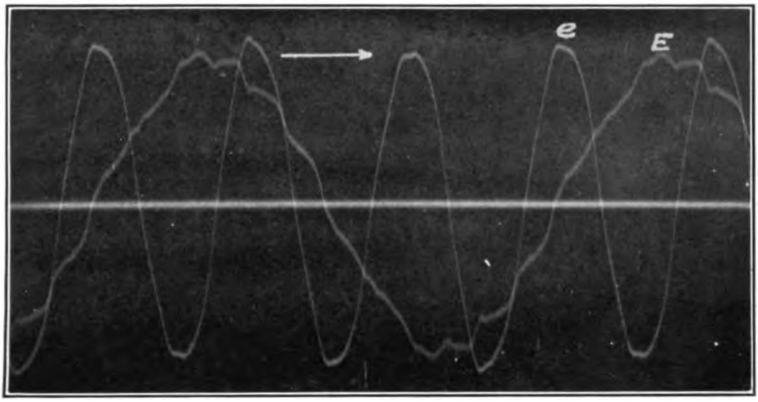
Figs. 10, and 11 show the voltage across the leg of the delta and amperes in the exciting lines. Densities 110 and 140 kilo-lines.

Fig. 12 shows voltage across the leg of the delta and amperes in exciting lines. Density 62 kilolines.

Fig. 13 shows voltage across the opening in the delta and across delta leg. Density 62 kilolines.

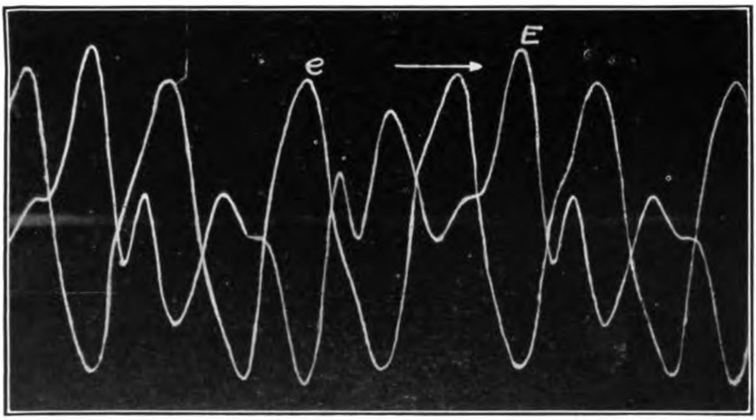
(In order to show these points of intensified triple frequency, there were set up in the hall the three 5-kv-a. trans-

*See *London Electrician*, May 8, 1914.



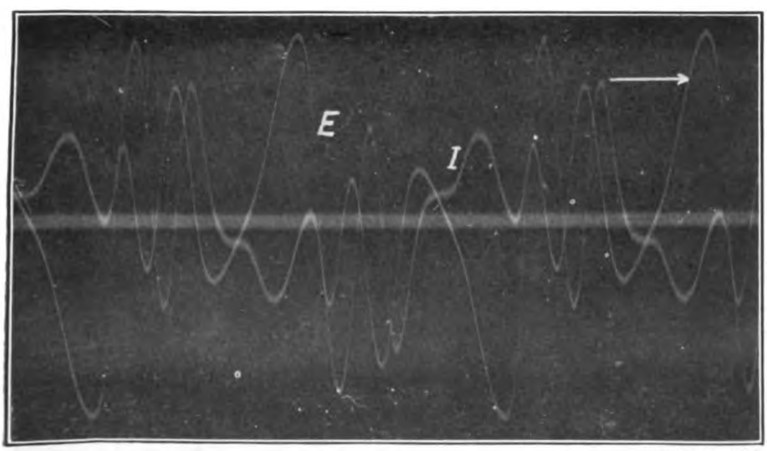
[MONTSINGER]

FIG. 8



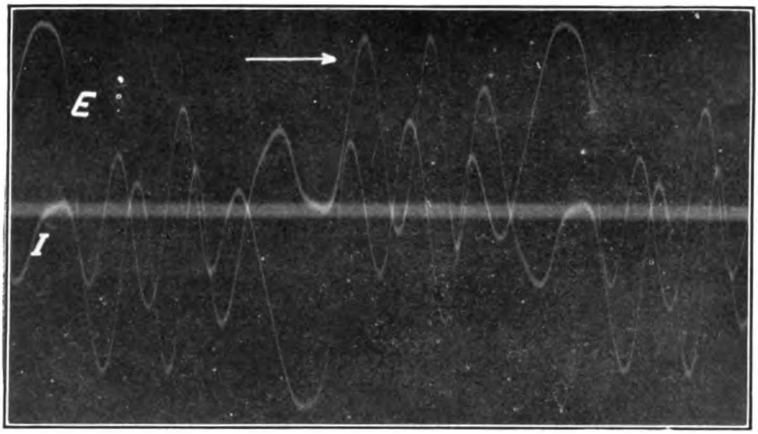
[MONTSINGER]

FIG. 9



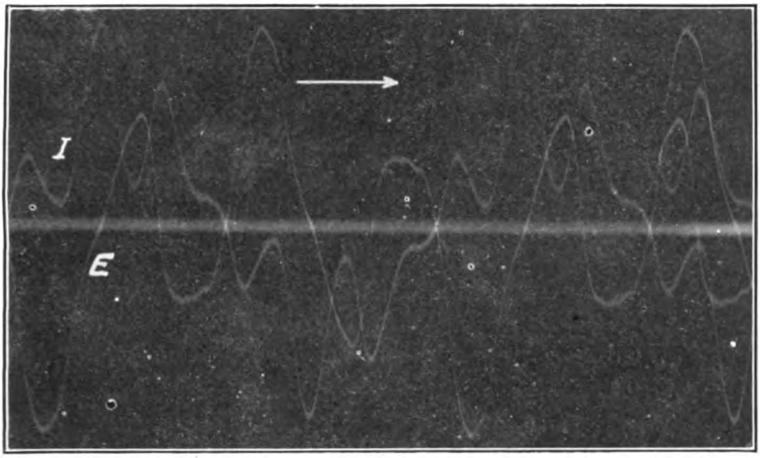
[MONTSINGER]

FIG. 10



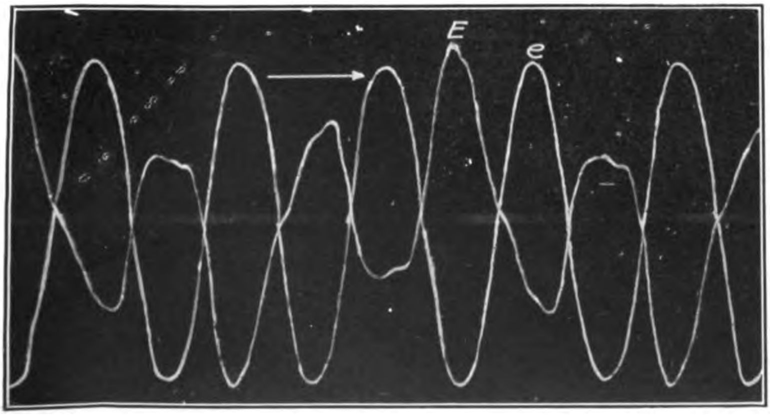
[MONTSINGER]

FIG. 11



[MONTSINGER]

FIG. 12



[MONTSINGER]

FIG. 13

formers and the 3-kw. generator and motor used in obtaining these curves. It was arranged that the shadow of the needle of the voltmeter, reading the volts across the opening in the delta, was thrown on the screen as it moved. The variations of the triple frequency volts, as the flux density was increased and decreased were shown: First, without the condensers; second, with the condensers across the delta legs, and third, with the condensers across the opening in the delta).

C. M. Davis: Does the maximum point shift up or down as the different capacities are placed across the opening in the delta?

V. M. Montsinger: This is the maximum point that I could obtain with this apparatus. If I added more condensers, the point would be lower and if I added less condensers, it would be still lower.

C. M. Davis: Does resonance, or something like that, affect it?

V. M. Montsinger: I do not think that it is a case of resonance.

C. M. Davis: If it were resonance, you would get that high peak occurring at different flux densities, would you not?

V. M. Montsinger: In some cases it does begin to rise again if we go to a still higher density, but in this case, it does not rise again; but with the larger generator, it does.

C. M. Davis: My point is that if it is a case of resonance, inserting a different capacity across the opening of the delta would cause the maximum peak to occur at different flux densities. For instance, instead of the maximum peak occurring at about 60 kilolines, with another condenser, it might occur at 40 kilolines and with still another condenser, it might occur at 70 kilolines.

V. M. Montsinger: As pointed out before, and as was shown in Figs. 3 and 4, it occurs at different flux densities for different capacities across the opening in the delta; the greater the capacity, the lower the density at which the maximum peak takes place.

L. F. Blume: The particular density at which the peak will occur depends on the electrostatic capacity, and the condition of saturation of the iron. If more capacity had been inserted, the peak would have occurred at a lower density. The reason the amount of intensification increases as the density increases, is the fact that the iron is operated at a higher degree of saturation, making the third-harmonic charging current less effective in increasing the third-harmonic voltage. I think that the phenomenon is not one of resonance, because a critical value of electrostatic capacity and reactance is not required to obtain the result. It is more analogous to the rise in voltage which takes place in a generator when delivering a leading wattless load. The third harmonic can be considered as being generated in the windings of the transformer on account of the variable permeability of the iron, which when connected to a leading wattless load is increased thereby.

H. S. Osborne: Several references have been made to the inductive interference caused in telephone circuits by the operation of parallel high-tension power circuits. In the paper by Messrs. Jollyman, Downing and Baum, the view is expressed that their grounded star-connected system causes less disturbance in telephone circuits than it would if connected in any other way. It should be noted that this remark is evidently given as a statement of personal opinion and not as a conclusion which has been established.

Whatever the relative amount of disturbance may be from star-connected and delta-connected power systems, it is certainly true that there is very severe interference with telephone circuits from the lines of the Pacific Gas and Electric Company under present conditions. There are in California many telephone toll circuits, the serviceability of which is in large measure destroyed because of inductive interference from the high-tension lines of the Pacific Gas and Electric Company under normal operating conditions. At times of abnormal conditions of the power circuits, parallel telephone toll lines or telegraph lines are put out of service by the operation or the destruction of the protective apparatus, and sometimes by the destruction also of cables or of central office apparatus. Interruptions of telephone service due to inductive effects resulting from abnormal conditions on power circuits have been noticeably more frequent per mile of parallel from the lines of the Pacific Gas and Electric Company than from the other high-tension transmission lines in California. This fact is not of itself necessarily an indictment of the grounded-star connection, because many of the other high-tension transmission companies in California used this connection, at least in part. Taking into consideration, however, the character of the disturbances, the experience of the telephone companies throughout the country would not incline them to support the authors' view, but rather the contrary conclusion.

An attempt has been made to compare the inherent features of delta and grounded-star connections in so far as their inductive effects are concerned. In comparing the relative inductive effects from different systems, it should be remembered that if the systems were perfectly balanced, that is, if the vector sum of the voltages between the line wires and ground were zero, and current in the ground were zero, the inductive effects from different three-phase systems would be similar. In considering the different systems, the comparison should, therefore, be made of the unbalanced components of voltage and current. A delta-star connected system with the neutral point non-grounded would have an electrical balance similar to that of a delta-delta connected non-grounded system. The comparison has, therefore, been made between the relative inductive effects due to the unbalances which occur in the delta-delta system and the delta-star system with grounded neutral.

This comparison is summarized in a table which is given below as a part of the record of this discussion. In brief, the comparison indicates that under abnormal conditions, either the delta-delta or the delta-star grounded system will make entirely inoperative telephone circuits which are severely exposed to them. The relative magnitude of the inductive effects under these circumstances depends largely on conditions. Under conditions of normal operation with balanced loads, the unbalances in the delta system may be reduced to a minimum. The unbalances in the grounded system may be restricted to the third harmonic and its multiples, and these may be of relatively small magnitude. With unbalanced loads, the inductive balance of the delta system remains good, but the inductive effects from the grounded system become severe.

In view of this analysis and of the experience of the telephone companies, the presumption seems to be against the grounded system. It is believed, however, that no one is at present in a position to make an authoritative statement regarding the relative inductive effects inherent in grounded and non-grounded systems. As far as I am aware no thorough study has been made of the relative possibilities of reducing interference from these two types of systems. Unless adequate measures are taken to minimize the inductive effects, the disturbances from systems of either type may be very damaging as the telephone companies can abundantly testify.

With the rapid increase in the networks both of telephone and high-tension power circuits, it is becoming increasingly difficult to keep the two classes of circuits adequately separated. It is, therefore, becoming more and more important that power circuits be constructed and operated in such a way as a minimize the disturbances which they cause in parallel telephone and telegraph circuits. If it should be found on thorough investigation that the inductive effects from grounded and non-grounded systems are substantially different in amount when each is provided with all the precautionary measures which are practicable and reasonable, then this consideration should be given its full weight in determining which type of transformer connection should be employed.

COMPARISON OF DELTA-DELTA AND DELTA-STAR GROUNDED CONNECTIONS FOR THREE-PHASE POWER TRANSMISSION CIRCUITS FROM THE POINT OF VIEW OF INDUCTIVE INTERFERENCE IN PARALLEL TELEPHONE AND TELEGRAPH CIRCUITS.

Delta-Delta

(a) Normal condition of Power Circuit.

Balanced Loads:

If line is well insulated, the voltages to ground are determined by the capacities between the ground and the line wires throughout their entire length and the capacities of all other

Delta-Star Grounded.

(a) Normal Condition of Power Circuit.

Balanced Loads:

Voltages to ground balanced to somewhat higher degree than transformer windings.

No fundamental current through neutral. Third harmonic magnetizing current and its multiples

lines in direct metallic connection to the line under consideration. Voltages to ground will be balanced provided entire system is so transposed as to equalize capacities between line wires and ground and provided system is without leaks.

Under these conditions no current will flow in the ground except a very small charging current between adjacent transposed sections.

circulate in delta windings. A sufficient amount flows through neutral connection and ground to provide e.m.f. for circulating currents. Currents flowing in ground may therefore be small but may cause disturbance in telephone circuits because of exquisite sensitiveness of telephone apparatus to currents of frequencies of the third and higher harmonics of 60 cycle systems. These harmonics are not essential to the operation of the power system, and means can possibly be found to prevent their flow through ground.

Unbalanced Loads:

Voltage unbalance to ground is caused by differences in impedance drop in the different phases. This effect small.

Currents is ground limited to unbalanced charging current. This effect small.

Unbalanced Loads.

Voltage unbalance to ground is caused by differences in impedance drop in the different phases. This effect is small.

Current unbalance equivalent to difference in load currents flows through neutral and ground. A small current causes relatively very severe inductive effects because locus of current in ground is far below surface and because current contains harmonics in addition to fundamental.

(b) Abnormal Condition of Operation.

One Wire Open:

Makes power system inoperative. Causes severely unbalanced voltages and severe interference in telephone circuits.

(b) Abnormal Condition of Operation.

One Wire Open:

Not always immediately discovered by Power Company. The total load current carried by the two conductors which remain in service returns through ground. Disturbances in telephone circuits very severe.

One Wire Grounded.

Not always discovered by Power Company. Voltages unbalanced throughout entire system with correspondingly severe disturbances in telephone systems. There is a danger of high frequency oscillations due to an arcing ground, although there is no record of trouble experienced by the telephone companies which has been definitely traced to this specific cause. In a great many cases the voltage unbalance with one wire grounded without the occurrence of an arc is of itself sufficient to render parallel telephone circuits inoperative.

One Wire Grounded:

Makes power system inoperative. Heavy current flowing through fault supplied from many lines in an inter-connected system gives very severe and widespread disturbances in parallel telephone circuits.

F. E. Haskell: Is the inductive disturbance chiefly electrostatic or electromagnetic; that is, to what extent will it occur?

H. S. Osborne: The question is asked whether inductive disturbance is chiefly electrostatic or electromagnetic. The relative importance of these two effects depends very largely indeed on the conditions of individual cases. Note should be made, however, of a marked difference in the ease with which the zone of serious electrostatic and electromagnetic effects can be limited.

The presence near the power wires of conducting or partially conducting bodies, such as overhead grounded wires or the earth, is much more effective in restricting the electrostatic field than in limiting the electromagnetic field. This difference arises partly from the fact that relatively small charging currents are sufficient to largely influence the electrostatic field and relatively large circulating currents are necessary to considerably limit the electromagnetic field. Unbalanced current from the power circuit flowing in the ground does not behave as though the ground were a perfect conductor, but distributes itself very widely and causes correspondingly widespread inductive effects. Generally, telephone and telegraph circuits have not been subjected to severe electrostatic disturbances, provided they are more than 200 or 300 ft. away from the disturbing circuit. Severe electromagnetic disturbances have, however, been experienced at considerably greater distances from the power circuits. An extreme case of electromagnetic induction is represented by the New Haven Railroad, which caused serious electromagnetic induction in telephone circuits about five miles from the disturbing circuits.

C. O. Mailloux: There is one point the speaker might have emphasized. The effects from electrostatic action are due to the combined effects of the line, whereas the electromagnetic effects are due to current passing through the line. That was clearly shown in the case of the very high potential transmission systems, in Michigan, a system employing over 140,000 volts, where the electrostatic induction in a telephone line situated at considerable distance from the power line was quite marked. That is clear from the fact that we know that electrostatic induction depends upon the potential of the line, whereas electromagnetic induction depends upon the magnetic field, which is itself a function of the current flowing through the line. The matter is of great interest, and I hope there will be discussion on it.

E. E. F. Creighton: In regard to the relative value of electrostatic and electromagnetic induction effects, it seems to me the electromagnetic effect from power circuits is and always will be a greater menace to telephone lines and any other parallel lines. The electrostatic can be taken care of in many ways that are practicable, but the electromagnetic seems to use such a depth of the earth, and forms such a large loop in conjunction

with the telephone line, that it makes it impossible to screen it in any way.

Some tests were made some time ago where the distance between the lines was 30 feet—they were on opposite sides of the roadway—the power line was grounded at the further end and the current was returned through the earth where there were salt marshes and consequently where one would expect the current to flow through the highly conducting surface. The values of induction between these two circuits were measured and from these measurements calculations were made of the equivalent loop of the primary and secondary, considering them simply as a transformer with one turn on the primary and one on the secondary. The equivalent loop gave a depth to the center of the current in the earth of 260 feet below the surface, consequently, although the wires were only 30 feet above the surface, one must consider the equivalent return circuit as at a great depth, and the possibility of screening the electromagnetic induction between these large loops of circuit seems almost hopeless.

John B. Taylor: It is a source of considerable gratification to me to see the trend of these papers on the matter of transformer connections Y versus delta, because, while I am not prepared to say I always favor the Y connection, I have had occasion in past years to recommend Y connections when I found myself in a minority. Just now it looks as though the pendulum is swinging the other way, and it may be well to put in a word of caution lest the pendulum swing too far.

This question of Y and delta connection is not ever to be settled by argument, or ever to be finally settled, because both arrangements have advantages, and the conditions under which they are used have been and will be variable, so that for a given system the advantages might lie with one connection or the other, in the future the same as they have in the past.

I would like to say that there is always a lot of confusion in discussing this point, which confusion has not been altogether absent in this discussion this morning; in other words, Y connection does not inherently mean grounded neutral. You can keep just as clear from the grounded neutral with the Y connection as you can with delta connection, so if you prefer to build your transformers with one or both parts connected in star, because of safe requirements, do not let the bugaboo of the currents in the earth keep you from doing it. There may be an advantage in tying to the earth at one or more points, but if it seem desirable to keep clear of the earth, that need not be the controlling factor in the connection of the transformer. This point always seems to be in evidence in a discussion of this subject and accounts for much of the discussion being altogether at cross purposes.

Mr. Blume draws some conclusions in his paper, and I am able to agree with all of these except the seventh, in which he

says, "it is necessary to solidly ground the neutrals at both receiving and generating ends of transmission lines." In my opinion the word "both" is open to exception. In general, the objections which may arise from grounding the neutral result from grounding at more than one point. Many of the advantages of the grounded neutral are perfectly well secured with the single ground, and many of the disadvantages are thereby avoided. Speaking in very general terms, I am inclined, with extra high-voltage work, to favor Y connections with the neutral grounded at one point only, and that is at the generating station. The case of the Pacific Gas & Electric Company is peculiar in that it has an extensive network, and there is no one generating station, as the logical point for grounding.

Mr. Fortescue refers to the possibilities of taking full advantage in saving insulation material with the Y connection. The transformer designed with the minimum amount of material to go on Y-connected system, with grounded neutral, might have practically no insulation at one end and full line insulation at the other end of the winding. With this form of construction it would not be possible to make the usual factory test of two or more times high-potential for a minute. Some means might be devised to satisfy the customer that the transformer is all right in spite of its inability to stand the customary high potential test.

In the paper dealing with the Pacific Gas & Electric Company system, Mr. Osborne has covered the principal points relating to telegraph and telephone matters, which I intended to make, and I can pass in the interest of saving time.

The contribution of Mr. Semenza refers to the Societe Conti transmission as causing telephone and telegraph troubles. I happen to be familiar with that particular case, and there, again, the trouble is due to grounding at more than one point, returning a considerable current of triple frequency through the earth, with accompanying induction in neighboring telegraph and telephone lines. Earth currents should be avoided in laying out a-c. systems.

Mr. Lewis has given an interesting summary of the connections in different plants in this country and other parts of the world. This table probably represents the opinions of manufacturing engineers, quite as much as the opinions of the operating company engineers. That this table shows the Y connections to be on the increase is worthy of notice.

The series of curves and the demonstrations Mr. Montsinger has made is an interesting example of what we may sometimes do with waste products. By-products sometimes come to be of more value than the original article of manufacture. The ability to obtain triple frequency from static transformers is, just at the present time, a little more than an interesting plaything,

and its value will probably be worked out in the laboratory rather than in the commercial field. The objection to the low power factor and limited output relative to the size and cost of the apparatus, would seem to work against this being a satisfactory scheme of power transmission, though it is certainly a great convenience if you have three-phase 60-cycle current at hand to connect three static transformers, push up the density and obtain a limited supply of current at 180 cycles. Some years ago I amused myself by operating an arc lamp at 180 cycles, which, on 60 cycles, flickered objectionably. There are possibilities that a 25-cycle system might use a limited supply at 75 cycles, where the 25-cycle flicker is objectionable. These appear interesting and special applications rather than possibilities of power transmission.

In England a Mr. Taylor has been advocating this frequency change, and I believe seriously proposed the use of it on 25-cycle railroads. As this would involve three-phase generators at $8\frac{1}{3}$ cycles, the costs and difficulties of obtaining 25 cycles in this case would appear to be much greater than the difficulties now holding for direct generation at 25 cycles, single-phase.

F. C. Green: For convenience in the discussion of this subject, the transmission system is divided into two parts: the transmission line, including high-tension switches and lightning arresters; the transformers connected to the line. Two classes of troubles are experienced with the transmission system; one affects the line and the other affects the transformers. High phase-voltages cause flash-overs of insulators, damaging the line; frequently burning off the wires and breaking the insulators. On the other hand, practically no troubles have been experienced with transformers on account of high phase-voltage. In almost every instance the trouble has been due to high-frequency produced by disturbances in the line. This division into two parts seems to be a natural one.

There are many points of minor importance to the main subject, and I agree with Mr. Taylor that a great deal of the work done on the papers and a great deal of the discussion have been spent on these minor phases, such as the triple frequency and its effects. So far as abnormal voltages are concerned, or dangerously heavy currents, the triple frequency does not need any further study because, as was pointed out yesterday, these effects can be entirely eliminated by a number of methods. If, however, for any reason it should be desirable to use a system of connections which would involve triple frequency effects, they can be eliminated as pointed out by Mr. Fortescue, in either interconnecting the phase windings, or in the interlinkage of the flux, as in the three phase, core type transformer. But, so far as can be seen, there is no reason for using such a system of connections, because the grounded Y-delta system eliminates all of these objectionable effects.

Another minor point that is brought out in the papers bears upon electromagnetic stresses. That is a question which manufacturers particularly, and in a limited sense, operators, have been very seriously interested in. But when we study into the situation, we find that troubles resulting from electromagnetic stresses, have been confined to those systems which have as their basis large turbine driven generators feeding into underground distributing systems, and in a lesser extent, to small transformers taking power from large capacity substations. In these installations, troubles have been experienced from electromagnetic stresses, but in overhead transmission systems, no troubles of consequence have been experienced. That is, the volume of these troubles is so small as to make them negligible in over head transmission systems.

The one point that, it has seemed to me, has the greatest bearing upon the whole question, has not been treated at all in any of the papers. Perhaps we may say that a very good foundation has been laid in the papers for building up a discussion on this vital point, but all of the papers are devoted to normal frequency effects. The grounded Y-delta is clearly shown to give much lower phase-voltage stresses than the delta-delta under abnormal system conditions.

With the isolated delta, in case of arcing from line to ground, observation convinces me that not only phase stresses are much greater, but also high-frequency stresses which cause transformers to break down between coils. In this particular feature lies the most vital part of the question. With the neutral grounded, arcing from line to ground is more steady than arcing in the isolated delta system. With the grounded neutral, there is a dynamic voltage across the arc, while with the isolated delta, the voltage from line to ground practically disappears upon the establishment of the arc. Under this condition, the making and breaking of the arc occurs more frequently. Since high frequency occurs only at instants of making and breaking and not during existence of arc, it is evident that the system of connections resulting in fewer makings and breakings of the arc, is the safer.

In one of the papers the point is made that for systems of 33,000 volts and below, the isolated delta system is more desirable because it is more flexible. If it is true that under arcing from line to ground in the isolated delta system, there are more repititions of high frequency strains, the argument advanced in favor of the isolated delta system for 33,000 volts and below, does not hold, for the reason that an arcing ground in a system of 33,000 volts or lower, would have the same tendency to produce high frequency and to cause the transformer to break down.

It is understood in this discussion that only the high-tension side of the transformers is connected in Y, and that the neutral of the Y is solidly grounded. Various other Y connections that have been enumerated are practically eliminated without discussion.

The possible use of two transformers in the delta system is advanced as an argument in favor of that system. Two transformers may be used with the grounded Y system, but not to the same extent as two transformers with the delta system; so that, even in this respect, the advantage is based upon degree rather than upon the nature of the system. The point has already been made of the great advantage in lowering the cost of transformers by having them designed for the grounded Y connection.

Another vital point in considering these two systems is the fact that with the grounded Y the location of a fault in the system is easy. Those who are familiar with the operation of plants know the importance of being able to locate troubles easily.

Mention has been made of the advantage in the delta system that one line wire can be grounded and the system continue in operation. I believe it is generally agreed that this applies only to short systems, or systems of low voltage.

P. M. Lincoln: This question of grounded neutral, versus an underground neutral is one which, I have always maintained, it is impossible for any man to sit down with a pad of paper and slide rule and figure out which way it should go. I think that this question is one of those which must be settled by experience, which must be settled by the man in the field, and for that reason I am very glad to read the paper by Messrs. Jollyman, Downing and Baum. I believe that the testimony of these gentlemen, operating men as they are, is of much more value and can be given greater credence than the testimony of those who simply sit down and look at this thing from the standpoint of the designing engineer. I think that it is a question which must be settled by practise rather than by the designer.

D. W. Roper: Mr. Fortescue in his paper makes a statement as follows: " In four-wire three-phase systems, where the e.m.f. is stepped up through the delta-star transformers, and three-phase power is supplied through star-delta step-down transformers the latter, if their neutral is connected to the neutral, serve as balancers for loads taken off between neutral wires and lines." That statement is quite correct, but it gives a very bad operating condition. It is much easier to obtain balanced voltage in other ways, by regulators on the individual phase wires, if regulation of voltage is desired.

Further, if you have a three-wire transformer bank of that kind with a transformer neutral connected to the system neutral, the blowing of the fuse on one of the transformers does not interrupt the customer's service, and is likely to result in a burnout of the other two transformers due to their overloading.

In Chicago both methods of operation have been tried. The scheme of grounding the transformer neutral to the system neutral was tried at first, but there were so many cases of trouble of that kind that the scheme was abandoned and the practise

is now universal, of connecting the three transformers for a power customer in star but leaving the neutral of the transformers entirely free from the neutral of the system.

One of the papers makes some reference to arcing grounds on a grounded neutral system, stating that they are, perhaps, not impossible, but are very rare. The system in Chicago, a four-wire, three-phase system with grounded neutral, has had a number of cases where an arcing ground has occurred and caused some disturbance. None of these have been very serious, but it is desired to call attention to the fact that such combinations were quite possible. An example may illustrate the point. A circuit operating normally suddenly had the switch opened automatically in the station. It was tried several times, in succession, and each time it again opened automatically. A few minutes later we heard that an auto truck ran into and broke down a pole and that the primary wires had fallen down into the street. Trouble men were sent to this location to clear up the local trouble and the circuit switch was again tried and again opened automatically. Further examination disclosed the fact that a lightning arrester had broken down some distance away, say half a mile, from the scene of the place where the wires were down, and this lightning arrester trouble was undoubtedly caused by the high-frequency and high-potential disturbance due to the wires being down in the street at the first location.

F. W. Peek, Jr.: I would like to call attention to a point which, it seems to me, is a most important one, and which has been overlooked in this whole discussion. I do not believe that the success of the transmission of energy electrically depends on whether the transformers are either Y or delta connected. We have actual practical demonstration of successful transmission with both systems. Troubles do not generally *originate* due to the energy of the transmission system, but to energy external to the system impressed somewhere on the transmission line. In most cases the transmission lines are very long and there is probably not a lightning arrester within many miles of where the trouble starts. Insulators arc over. The energy of the system then enters, and adds to the trouble, as over-voltage or over-current, or both. Damage to apparatus may be due to lightning directly, or by the transient voltages or short circuit current of the system energy following the lightning discharge.

Laying aside, for the moment, the relative merits of one system or the other, the most important point in transmission, and the one that I wish to emphasize, is the insulation of the transmission line. The transmission line should be insulated just as well as is economically possible, in order not to make lightning arresters of the insulators. When insulators arc over, the result is a short circuit or an "arcing ground." The arc is not under control. The line insulation should be such that the lightning arrester has a chance to discharge. The arc is

then under control and is suppressed before appreciable damage results.

There are many inconsistencies in the way in which transmission lines are insulated. I will take an actual line as an example. In a certain part of the country where the lightning is very severe there are two independent lines along the same right of way. One line is operated at 22,000 volts, and thus has two suspension insulator disks in series, or operates at 11,000 volts per disk in terms of line voltage. The other line is a 100,000-volt line and has five disks, or 20,000 volts per disk in terms of line voltage. According to the general method of reasoning, the factor of safety of the low-voltage line is twice that of the high-voltage line (assuming good insulators). This is so in terms of the normal 60-cycle voltage, but it is not the normal voltage which starts the trouble. It is lightning. The arc-over voltages of the insulators on these lines are probably 160 kv. and 320 kv. respectively, while the puncture voltages are about 35 per cent higher. There was great surprise that all the trouble was on the low-tension 22,000-volt line, although it had a higher "factor of safety." Transient voltages induced on these lines by lightning probably range from 200,000 to 400,000 volts, with occasional voltages above the maximum of the range, and the majority below the minimum. Both lines are subjected to the same lightning voltage. The low-voltage line has practically no factor of safety in terms of the lightning voltage, as this abnormal voltage is often above 200 kv. The puncture voltage (about 420 kv.) of the higher voltage line, except in rare instances, is greater than the lightning voltage generally induced upon the line. The factor of safety, as ordinarily expressed, has very little bearing as an indication of probable failure. In the case cited the "factor of safety" was seven on the low voltage line and three on the high voltage line. Either line would have operated equally well in a country free from lightning, as in California. The "factor of safety" should be much higher for low-voltage lines than for high-voltage lines when such lines are subjected to lightning. Of course, it is important to determine how far the insulation shall be carried out and what the factor of safety shall be. I have noticed in certain sections of the country, where lightning troubles are very severe, that when more than four or five disks are used in series there is very little trouble from lightning. Where a smaller number of disks are used the troubles are greater. Of course this also applies to pin type insulators, the number of disks merely indicating the value of the insulation. Line troubles decrease as the insulation is increased because the insulation breakdown voltage approaches or becomes greater than the induced lightning voltage. Arcing takes place over the arrester where it may be suppressed. Great damage is done by arcing following a lightning stroke.

The effect of the initial lightning stroke will be practically

the same with either delta or Y connection. The after effects due to arcing, etc. will, however, be different. In selecting insulators the mechanical side should not be lost sight of. Insulators may pass electrical tests very well, but develop small cracks when put in service, due to poor mechanical design. Failure occurs due to ordinary line surges. It is often, then, assumed that high voltages exist when, in reality, the insulators have become bad.

Great caution is necessary in making a diagnosis of a failure in apparatus, as transformers. Failures have often been attributed to over-voltage which were really due to the mechanical strains of over-current. Such failures may take place at the first slight over-voltage because the insulation has first been damaged mechanically by over-current. Mistakes in the opposite direction are also easily made.

It is not my intention to go far into the relative merits of either system. Either system may be a success with proper line insulation and proper operation and inspection. The choice depends a great deal upon whether there are a number of power houses and a network, or only one power house, whether reliability of service is the all-important factor and can be paid for, etc. This is especially so at low and moderate voltages, where the delta system is most often desirable on account of its greater flexibility and reliability. At very high voltages and with very long lines the advantages of the delta are lost somewhat and the grounded Y may be used. For instance, under these conditions the charging current and corona current with one line grounded may approach short-circuit current. An accidental ground on such an isolated delta system may thus cause large current to flow. This large leading current flowing through a reactance will cause abnormal voltage. The cost of the apparatus may have a bearing in favor of the grounded Y at very high voltages.

When comparisons are made of different systems in different parts of the country, to determine the relative advantages of delta or grounded Y, "shut-down" data should always be given, otherwise comparisons are almost valueless. A statement of satisfactory operation is not sufficient, as the term has decidedly not always the same meaning.

J. R. Werth: I should like to have Mr. Fortescue in summing up his paper, advise us in regard to his tabulation where he says "Y-grounded direct or through resistance." I should like to know whether he has any data indicating whether any of these systems are grounded through a reactance, in other words, has the reference to the reactance been omitted because none of these systems was operated, or has it been omitted simply because he considered it not pertinent to the discussion?

Louis F. Blume: In reply to Mr. Taylor's objections to the complete association of the delta-Y connection with the grounded system, I believe that this has been inadvertently done through the emphasis on the discussion of grounded vs. isolated systems.

Obviously a grounded system must be delta-Y and a delta-delta system must be operated ungrounded. From this has arisen two questions:

1. Grounded systems vs. isolated systems.
2. In isolated systems the delta delta connection vs. delta-Y connection.

As by far the larger number of delta-Y installations are operating with grounded neutral, and also as the first of the above questions possesses the greater importance, the term delta-Y has come to denote a grounded system.

Mr. Taylor objects also to my conculsion that "If it is desired to limit the value of potential at fundamental frequencies above ground of any part of the system to 57 per cent of line potential, it is necessary to solidly ground the neutrals at both receiving and generating ends of transmission line." I am perfectly willing to remove the word "both" in the above statement provided it is applied only to transmission lines in which the kv-a. capacity of the step-down transformer groups is practically equal to the kilovolt-amperes capacity of the step-up transformer groups, but if the step-down units are small compared with the size of the step-up units, and particularly if the step-down units are scattered over considerable territory, which is the case when a generating system is supplying power by means of a large number of feeders, it will be necessary to solidly ground the neutrals at both ends if potential stresses at fundamental frequencies are to be limited to 57 per cent of line voltage.

Mr. Semenza and Mr. Osborne have both spoken of the effect on the operation of telegraph and telephone lines of operating systems with neutral grounded. Under normal conditions of operation there is no difference between a delta-Y grounded system and an isolated delta system as far as the effect on telephone and telegraph lines is concerned, unless the grounded system carries an unbalanced load between line and ground. The latter case constitutes a four-wire system in which telephone troubles are caused by unbalanced loads. Obviously, troubles from this cause should not be given as an objection to the operation of transmission lines with grounded neutral, but should be considered only as a valid objection to the loading of three-phase systems from line to ground.

Telephone and telegraph interference resulting from third harmonic current flowing in the ground under certain conditions of transformer operation should not be considered an objection to the grounded Y system, because as Mr. F. C. Green has pointed out, in all properly designed transformer connection such troubles are entirely eliminated.

Mr. Peek has raised a number of interesting questions, and intimates that there can be potential disturbances on grounded systems, and also current disturbances on isolated systems. Undoubtedly this is true, and it is to be regretted that more

definite information concerning this feature has not been presented.

In general, I agree with the various members, who have said, that the papers as presented do not completely cover the question under discussion. There are a number of troubles which occur on transmission lines which have a very vital bearing upon the question, and which have only been casually mentioned. On this account it is very difficult for us at the present time to form any definite conclusions as to the relative superiority of either system.

C. L. Fortescue: In closing the discussion on my paper, it seems necessary only to sum up what has been said by previous speakers, since most of the questions asked by certain speakers have been answered by others.

However, I will first touch on the papers by some of the other authors, which deal with questions treated in my paper. In the paper by Messrs. Sorensen and Newton, which was read yesterday, tests were made on Y and delta connections, and some very radical conclusions were drawn. I may state that I have gone over these tables carefully, and find no basis for these conclusions I notice that many necessary data are missing. There is no information as to the primary voltage and the secondary voltage of the transformers, the type of generator, how it was driven, and we do not know whether the iron in the transformers was saturated or at normal induction, in other words, we have nothing in this paper to enable us to draw our own conclusions.

The authors' conclusions are, I might say, somewhat dogmatic. In one paragraph this statement is made:

"When transformers were made in small sizes only, particularly if they were shell type, there was some advantage in having the windings connected Y for the high-tension side of the bank, as this allowed a smaller number of coils and less insulation, because the normal strain was 57.7 per cent of that of delta-connected transformers. The increase in size of units and the provision for maximum strain where one line becomes grounded have made these economic advantages obsolescent, except in some very special cases of small, high-voltage units. Hence, from the point of design and manufacture, there is no advantage for either Y or delta construction."

This is puzzling. I feel that I cannot agree with this statement. I think, now that we are getting higher voltages, even such a little difference as a normal potential stress of 57.7 per cent of line voltages against 87 per cent, becomes of more and more importance.

There is one point in Mr. Blume's paper that I would like to call attention to, namely the question of operating delta banks in multiple with open delta banks. Mr. Blume says that when two or more delta banks are operated with an open delta bank, the total capacity is somewhat lower, but that by inserting

reactance in series with the remaining phase the capacity would be considerably increased. The better way of operating such banks in multiple would be to insert reactance coils equal to the effective reactance of one transformer in the apex of each of the open delta banks. This produces in an open delta the same effect as a balanced delta connection. The banks will then divide the load as if all the systems were balanced. By inserting the proper impedance in each line of the remaining banks the delta connected banks may be operated at full capacity without overloading the open delta connected banks.

In regard to the discussion on my paper, Mr. Taylor has pointed out, that there is some confusion as to the manner of operating delta-delta and delta-star connected banks of transformers. There seems to be an impression in the minds of a great many of the people who have discussed this matter that delta-star connected banks necessitate grounded neutral. I want to emphasize what Mr. Taylor has already said, namely that the delta-star can be operated just as well without the grounded neutral, and it also has some other decided advantages which have been sufficiently dealt with in my paper. The points which Mr. Green intimated had not been touched on are also referred to in the paper.

The characteristics of the transmission lines and local conditions, as Mr. Peek has brought out, are the predominating influences, so that in some cases in the delta connection the troubles are current troubles as against the usual voltage troubles and in some cases in the Y connection the troubles are voltage troubles as against current troubles.

In connection with telephone troubles in grounded systems, the delta-star step-up transformer almost entirely eliminates the third harmonic. It does not eliminate it entirely, because of the drop through the effective primary impedance, due to the magnetizing current, which has harmonics of the third group This produces a small third harmonic pulsation in the neutral, which may have an amplitude of the order of ½ per cent, or lower, of the line voltage, but, is not of sufficient magnitude usually to produce telephone troubles.

I think, as Mr. Blume has pointed out, that the telephone troubles in star systems have been due largely to Y-Y connected systems in which the neutral of the Y is connected with the neutral of the generator. The generator nearly always has a triple harmonic component in the voltage between neutral and line, which is transformed in the secondary, and the charging current to ground due to this component even when small may be extremely large, as has been pointed out in the discussion, and causes telephone troubles. Also it is a very common practise, at least in the West, in sparsely populated districts, to load between one wire and ground, which is also very bad practise as far as telephone circuits are concerned.

To sum up, it seems that sufficient regard has not been taken

of the advantages of the delta-Y system ungrounded as against the delta-delta system. It has decided advantages, which should be given consideration. In fact, the higher the voltage, the greater are the resulting advantages. In my paper I have stated that, if the voltage is above 44,000, generally speaking, the star connection grounded or ungrounded has the advantage.

There was a question asked as to the use of reactance in series with the neutral to limit the short circuit current. I have no data as to whether any of these systems mentioned use reactances or not. About seven or eight years ago, a system came under my observation in which the neutral point of a star-connected auto-transformer was to be grounded. The neutral point was first of all solidly grounded, which resulted in considerable disturbance in neighboring telephone circuits. Grounding through reactance was next tried and much to the surprise of the experimenters the disturbance was increased; the more reactance they put in, the more charging current they obtained. I rather think that a reactance is not the proper thing through which to ground the neutral point.

I think Mr. Roper made the statement that it was inadvisable to connect the neutral point of star-delta step-down transformers to the neutral wire in the four-wire system. Generally, the four-wire system is operated from the generator, and since a triple harmonic is usually present between the neutral wire and the lines, if the neutrals of generator and transformer bank are connected through this wire a third harmonic will circulate, which is a bad feature. "In four-wire three-phase systems, where the e.m.f. is stepped up through delta-star transformers and three-phase power is supplied through star-delta step-down transformers the latter, if their neutral be connected to the neutral wire, serve as balancers for loads taken off between neutral wires and lines." The delta-star bank of step-up transformers eliminates the third harmonic, and permits the breaker to open when there is a ground or short circuit on the customer's line.

Max H. Collbohm (by letter): The paper presented, discussing the relative merits of grounded and ungrounded transmission systems, seem to be quite generally in favor of the grounded system, both from the standpoint of safety to equipment and convenience of operation. The writer's experience with a number of grounded and ungrounded transmission systems has prompted him likewise to give preference to the grounded system provided certain precautions are taken to guard against service interruptions in case of an accidental ground on the line which ordinarily would cause a short circuit on one phase and open the line switch.

In a recent article* the writer discussed a scheme for protecting a grounded system against service interruption, which consists of a metallic grounding rheostat between the transformer neutral

*"Service Continuity in Grounded Transmission Systems." Max H. Collbohm, *Electrical World*, April 18, 1914.

and ground for reducing the current through the ground, and a special instantaneous circuit-opening relay inserted in the tripping circuit of the line switches and energized from the secondary of a current transformer, the primary of which is connected in the lead from the grounding rheostat to ground. Through this arrangement an automatic opening of the line switches by an accidental ground on the line is prevented, as the special circuit-opening relay energized by the ground current opens the tripping circuit of the line switches before the inverse-time overload relays of the line switches have closed their contacts. An ammeter, alarm bell and signal lamp inform the attendent of the existence and severity of the ground and permit him to isolate the line in trouble without service interruption.

The article mentioned gives a description of other protective features as well and records also the actual operating results obtained during the lightning season of 1913 in the system of the Peninsular Power Co., Iron Mountain, Mich. (66,000 volts, 40 miles) which had been equipped with the protective equipment described in said article. As will be noted the system went through nineteen lightning storms of more or less severity with only four seconds of interruption due to lightning, or practically none at all. It is a significant fact that not even a single insulator became damaged by lightning in spite of a large number of accidental grounds over them, which fact is evidently due to the installation of upper and lower arcing rods on each string of insulators.

These results seem to indicate that practically absolute continuity of service can be maintained in a grounded system, if properly equipped, with perfect safety to the equipment and convenience of operation.

Presented at the Pacific Coast Meeting of the American Institute of Electrical Engineers, Spokane, Wash., September 10, 1914.

(Subject to final revision for the Transactions.)

ELECTRICITY IN THE LUMBER INDUSTRY

BY E. F. WHITNEY

ABSTRACT OF PAPER

The development in the application of electric drive to the lumber industry has been exceptionally rapid. Successful sawmill companies are now even operating entirely from central station service, notwithstanding the large amounts of refuse available for fuel.

The paper considers the lumbering industry as carried on in Washington and Oregon, and describes the application of electric power to the various operations carried on under the two main divisions of logging and milling. Typical applications are described, to illustrate types of motors and power transmission equipments, and the average power demands of the various logging operations and milling processes. In addition to the machines used in ordinary sawmill work, those used in planing mills and shingle mills are described. The question of the disposition of waste is considered, and comparative fuel values are given. The illustrations show logging operations and electrically driven saws, finishing machinery and lumber-handling machinery in the Pacific Coast lumber districts.

THE first comprehensive applications of electric drive in the different branches of the lumbering industry are of such recent date, and the individual installations vary to such an extent, that no general treatment of the subject could be undertaken until more well-defined practises were settled upon.

Not more than four years ago a completely electrically-operated sawmill was considered a hazardous undertaking; today, a new mill adopting other than the electric drive is the exception. The results of such operation have been so gratifying that today we can show two large and successful sawmill companies operating entirely from central station service, in spite of the large amounts of refuse available for fuel.

The first completely operated mill was put in operation about 1908; the total installation consisted of 800 h.p. connected load, with a generating plant capacity of 600 kw. The first electric logging engine was put in commercial service in 1912. The electric railway, used solely for logging purposes, is yet to come.

Before the above date many special machines—and often complete planing mills—were driven electrically, but none were

willing to pioneer such drives for the heavy duty sawmill machinery required for Coast conditions. There is necessary today but one further step, viz., a drive for the cumbersome log carriage that will compare favorably in first cost with the simple twin engine, and the necessity for steam will be entirely banished from the milling branch of the industry.

The lumbering industry, as a whole, must be divided into two distinct classes of work for our consideration: logging and milling.

Under the first heading we have the following operations: felling the trees: cutting to desired lengths: gathering from the woods: loading: hauling to distribution centers: unloading: sorting: rafting and towing.

Under "milling" come the manufacturing plants and their various processes, which must be divided into: saw mills: planing or finishing mills: specialty mills.

The Pacific Coast and Northwestern States, together with British Columbia, contain two-thirds as much standing timber as there is in the entire United States; Oregon contains approximately one-fifth, Washington one-seventh and California one-seventh. In lumber production Washington, Oregon and California rank, respectively, first, fifth and fourteenth and their combined output is one-fifth of the total cut of lumber in the United States. The sawmills alone in these three states require approximately 240,000 h.p. for driving their mill machinery. Further than this, in the two northern Pacific Coast states, viewed from the point of manufacturing industries, the lumber production is of even greater importance; for instance, in 1913 the value of the lumber mill output in Oregon was approximately one-third of the total value of the manufactured products in that state.

Logging

In the branch of the industry embraced under the heading "logging", progress in the application of electric drive was very slow. It is only of recent years that power-driven logging machines have met with general favor, supplanting the old ox team. The flexibility of steam engines under the very severe demand imposed in such work, was thought to be an insurmountable obstacle to the adoption of any other system; for instance, the loggers demand an equipment which can stand very heavy overloads momentarily imposed and which, at the same time, has flexibility enough to allow the progress of the log to be stopped almost instantly should it encounter an obstacle.

At the present time it is estimated that there are approximately 3000 steam-driven logging engines in the two states of Washington and Oregon. Most of these outfits are twin-cylinder engines approximately 10 by 12 in. (25.4 by 30.48 cm.). The average operating boiler pressure is 160 lb. (72.5 kg.) gage, so that they have great capacity for intermittently imposed heavy overloads. From the viewpoint of electric operation this requires a motor which will seldom come anywhere near its continuous capacity, but which will frequently be called upon to exert its maximum torque.

In these two states the operating companies total 532, with an output of 7,080,000 M. ft. (board measure) or about 23,600 M. ft. (board measure) per day. The scene of their operations is often far removed from railroads; in the above operations the average distance from the scene of logging operations to the mill or to tidewater, varies from one to 35 miles (1.61 to 56.3 km.). The average distance is approximately 15 miles (24.15 km.). The maximum distance of which we have record that logs are handled by rail in either of these two states, is 120 miles (202.1 km.), and by towing—after reaching tidewater—125 miles (210.1 km.).

An added drawback to the use of electricity in the camps was discovered in the distance of the operations from the centers of power generation or present transmission lines.

Logging operators demand the simplest possible outfit, which necessitates the adoption of alternating current for such work.

The average cost to the logging company of logs at the boom is approximately $8.00 per M. ft. board measure. This is divided approximately as follows:

Fixed charges	17 per cent
Logging (including felling trees, gathering and loading)	50 " "
Hauling by rail	11 " "
Handling at boom (including unloading, sorting, rafting and towing)	9 " "
Stumpage	13 " "

We therefore see the great expense to the logger in felling the trees and gathering them from the woods, and in hauling them to tidewater. It is in connection with these two items that electricity has its greatest possibilities.

There has been developed, for the logging engine, a motor which has all of the characteristics demanded, viz., heavy construction; ability to stand severe overloads; ease of control and no complicated parts. After exhaustive tests the Potlatch

Lumber Company put the first two electric logging engines into commercial operation in 1912*. These outfits operate on an overhead system, lifting the logs from the ground and letting them come in practically by their own weight in hillside work, or pulling them in when working in flat country. Typical operating data are given in Mr. Barry's paper.

Motor Equipments

The motor equipments shown in Figs. 1, 2 and 3 are adjustable-speed 150-h.p., 600-rev. per min. synchronous speed, 550-volt, three-phase, 60-cycle induction motors. Power is received at portable transformer substations—one substation for each equipment—at 11,000 volts and is stepped down to 600 volts for use at the motors. See Fig. 4. Rubber-covered armored cables run along the ground from the substation to the motor, the distance never exceeding 1000 ft. (304.8 m.).

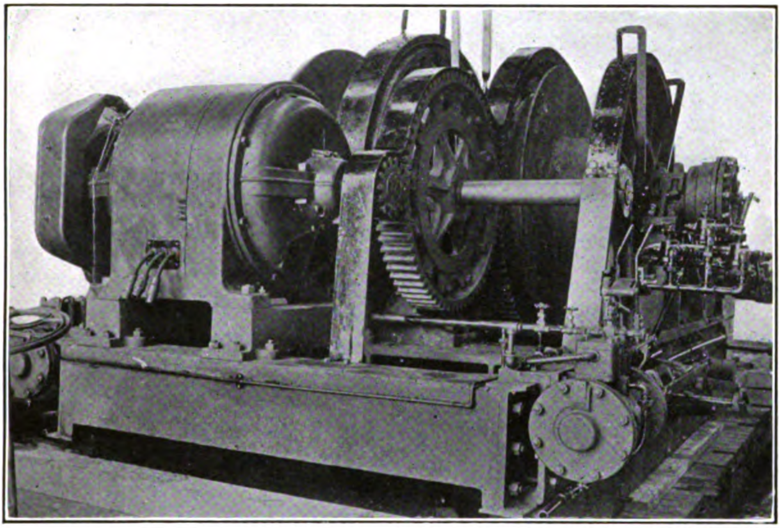
In order to prevent mechanically over-taxing the equipments, an inverse-time-limit overload oil switch is set to give practically instantaneous operation when the pull upon the main cable reaches its breaking strain. For quickly starting or stopping and to prevent overwinding the cable, a solenoid brake is mounted on the front end motor shaft extension.

These outfits are also called upon to load the logs on cars and to spot the cars, and even under these conditions the electrically operated outfits hold the camp record for a day's operation, viz., 55,000 ft. board measure, gathered and loaded by one logging machine in one day. This quantity is comparative only to this company's other operations; the capacity of steam donkeys under similar circumstances is 40,000 ft. per day.

The following table gives representative performance figures for the various operations:

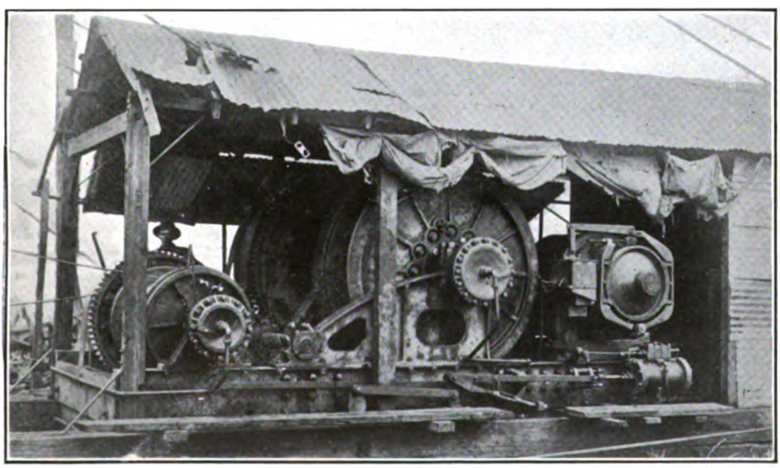
Work Performed	Input	Duration.
Tightening standing line, 2800 ft. of 1¼-in. steel cable	260 kw.	10 sec.
Running trolley out	Accelerating, 100 kw.	
	Running free, 35 kw.	40 to 60 sec.
Pulling trolley in with logs;		
1 log, 800 ft. b. m.	70 kw.	40 sec.
4 logs total 2000 ft. b. m.	145 "	65 "
3 " " 1600 ft. b. m.	210 "	60 "
1 log " 1100 ft. b. m.	85 "	70 "
1 " " 1800 ft. b. m.	95 "	90 "
Loading logs on cars	max. 100 "	
	min. 70 "	3 to 5 sec.
	avg. 85 "	
Moving cars	max. 225 "	
	min. 25 "	3 to 5 sec.

*E. J. Barry—A.I.E.E. Proceedings, September, 1913.



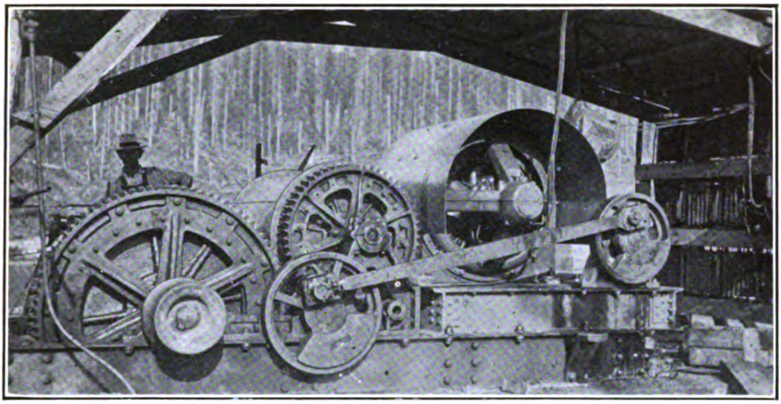
[WHITNEY]

FIG. 1—FRONT END, ELECTRIC LOGGING ENGINE



[WHITNEY]

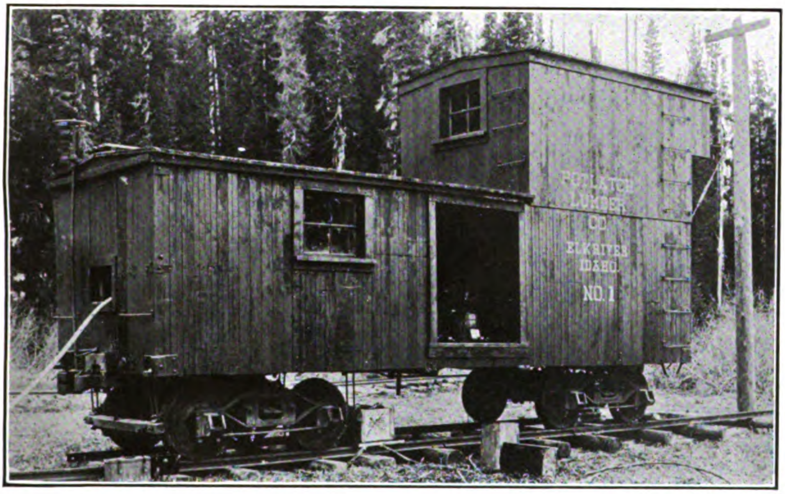
FIG. 2—ELECTRIC LOGGING OUTFIT MOUNTED ON SKIDS AT SCENE OF OPERATION



[WHITNEY]

FIG. 3—FIRST TRIAL OUTFIT, USING STANDARD MOTOR EQUIPMENT

This outfit operated successfully under varying conditions for a period of three months, to obtain data for later applications.

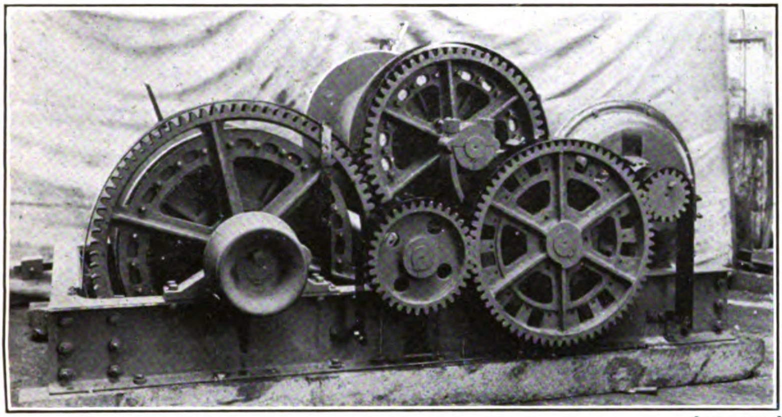


[WHITNEY]

FIG. 4—PORTABLE TRANSFORMER SUBSTATION, 11,000 TO 600 VOLTS. ARMORED CABLE LEADING TO LOGGING ENGINE AT LEFT

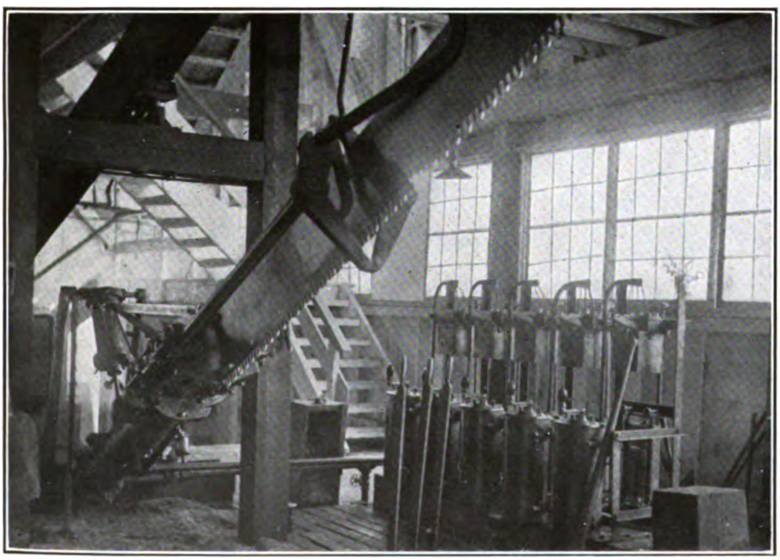
[WHITNEY]

FIG. 5—GENERAL VIEW OF POTLATCH LOGGING OPERATION. ELECTRIC LOGGING ENGINE AT LEFT, SUBSTATION AT RIGHT.



[WHITNEY]

FIG. 6—LOGGING ENGINE OF C. A. SMITH LUMBER AND MANUFACTURING COMPANY AT MARSHFIELD, OREGON



[WHITNEY]

FIG. 11—LOG SAW ON LOG DECK IN MILL. CONTROL FOR LOG HAUL AND CONVEYER CHAINS SHOWN AT RIGHT

In all of the above operations the load is of short duration, so that the daily energy consumption is small. For a 10-hr. day approximately 400 kw-hr. are consumed gathering and loading 50,000 ft. b. m. Fig. 5 shows a typical logging scene in this country. Fig. 6 shows the type of equipment adopted by the C. A. Smith Lumber & Mfg. Co. It is intended for hauling logs on the ground by the old method of "skidding". The motor is wound for 2200 volts. This pressure has been adopted by this company as most economical under its conditions, which require that it cover at least one mile in every direction from a distributing point, to several operating locations. A permanent 60,000/11,000-volt substation in the center of its holdings will distribute to three or four 750-kw., 11,000/2200-volt portable substations, each feeding one unit of its operations.

Of late, a great deal of attention has been given to the use of oil fuel and coal, as well as wood, for logging engines, and in order to see the comparative operating costs the following figures, covering fuel and labor for a logging engine only, have been prepared. These figures are based upon operations under similar conditions in the same camp and doing the same general work.

Average quantity handled per day	76,200 ft.. b. m.*
" distance of yarding	670 " (204.2 m.)
" size log	1900 " b. m.*
" time per log	15 min.
" wood burned per day	1650 ft. b. m.*
" fuel oil per day	†8.8 bbl. (11,192 liters)
" coal per day	2½ tons (2.245 metric tons)
Electric power energy consumption	475 kilowatt-hours

Outfit working 70 per cent of time—delays 30 per cent of time.

*In *lumber scale* 1 ft. b. m. is the equivalent of a board 12 in. (30.48 cm.) long, 12 in. (30.48 cm.) wide and 1 in. (2.54 cm.) thick, or 144 cu. in. (2359.7 cu. cm.). The *log scale* considers all items of loss in manufacture and endeavors to allow for these losses so that the log estimate and lumber production may approximately agree. It considers loss due to saw kerf, defects in log, varying diameters at top and butt, etc. There are several rules used in different localities—one will under-estimate the lumber in small logs—another will under-estimate large logs—and the third (which is rather generally used on the Coast) gives a mean value, approximating more closely conditions as found. The above values refer to log scale and therefore represent a greater cubical content than would be the case after same was manufactured into lumber. A very good comparison is given by the following:

1000 ft. b.m. log scale weighs approx........8000 lb. (3628.8 kg.)
1000 " " lumber scale (green lumber)...3300 " approx. (1497 kg.)
† 1 bbl. oil = 336 lb. (152.4 kg.)

Electric Operation:	
475 kw-hr. at 1½c. per kw-hr.	$ 7.13
One motorman	3.75
Total per day	$10.88
Oil Operation:	
†8.8 bbl. at $1.15 per bbl.	$10.12
Engineer	3.75
Water—(based on ½ of pumping engineer's time and ½ fuel consumption for pumping engine)	2.67
Total per day	$16.54
Coal Operation:	
2½ tons at $4.25	$10.62
Engineer	3.75
Water (see Oil Operation)	2.76
Total	$17.13 (per day)
Wood Operation	
1650 ft. b. m. at $7.00 per M	$11.55
Engineer	3.75
One wood bucket	2.75
Water (see above)	2.88
Total per day	$20.93

The fuel costs given above are arbitrary and are taken as general averages. It is questionable whether oil and coal can be delivered to the donkeys for such a low price, considering all items—handling, storing, pumping, etc. Without doubt, the cost of fuel would be higher than the value assumed, in the majority of operations. The cost of wood for fuel is estimated as follows:

Stump value	$2.50 per M.
Logging cost	4.00 " "
Extra cost for placing behind donkey	0.50 " "
Total	$7.00 per M ft. b.m.

The higher interest charge in the case of electric operation due to first cost of transmission line, substation, etc., is more than offset by the very much greater depreciation in the case of steam-operated outfits. No attempt has been made to cover this item for all cases. As a conservative estimate, however, the maintenance of a logging engine boiler 72 in. diameter by 144½ in. long, with 374 two-in. tubes, is not less than $200.00 per year, and in view of the severe service its useful life will not exceed eight to ten years.

Averaging the above costs for fuel and labor, with oil, wood and coal, shows a net saving of $7.35 per donkey per day in favor of electric operation.

An electric unloader is used which dumps the logs from the

cars at tidewater. This is operated by a 37-h.p. hoist motor, and unloads 30 cars, each containing 7000 ft. b.m., in approximately 20 minutes. This time includes that necessary for spotting the cars at the log dump. This unloader used a total of 90 kw-hr. for unloading 4000 M. ft.

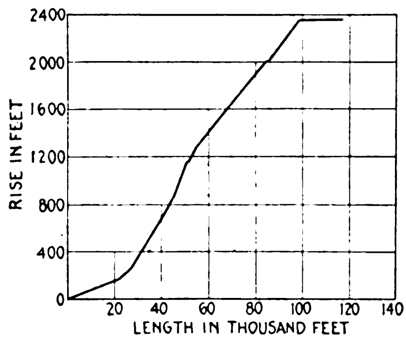


FIG. 7—PROFILE OF LOGGING ROAD NO. 1

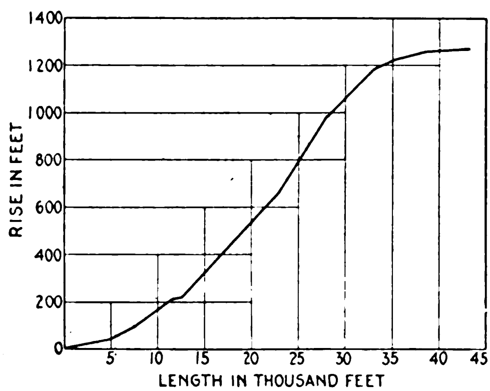


FIG. 8—PROFILE OF LOGGING ROAD NO. 2

LOGGING RAILWAYS

Figs. 7 and 8 show typical condensed profiles of two logging railways. Usually the country to be tapped is rugged and mountainous, necessitating heavy grades and sharp curves. Track construction is as light as possible. As a general rule the grade is in favor of the load and in most cases very little energy is required on the down or loaded trip. Oil is the common fuel. Because of the grades encountered slow speed locomotives find

a wide use, the slow schedule speed requiring train operation almost continuously during working hours. The lengths of these roads are usually very favorable to electric operation, allowing a round trip to be made in a reasonable time and not necessitating a train of excessive length.

In only three of the thirteen counties in Washington and Oregon which produce 88 per cent of the timber in these states is the average length of haulage less than thirteen miles. An average of the thirteen counties shows a main line length of 15.2 miles. The maximum grades are usually from 5 to 7 per cent for an appreciable distance, with curves up to 20 degrees. The average grade through the line is seldom less than 2½ per cent and spurs leading to the different camps have even heavier grades and sharper curves.

An analysis of operation is very favorable to electricity, as will be seen by the following data, which give conditions of a typical road:

General Data:

Length of line	21½ miles.
Average grade with load and against empty cars	2 per cent
Maximum grade, including equivalent friction for curves	5.5 per cent.
Gage of track	4 ft. 8½ in.
Weight of rails	60 lb.
Loaded cars to be delivered per day	75
Weight of car empty	18½ tons.
" " " loaded	50 tons.
Operation	
Weight of locomotive	60 tons.
Cars per train either direction	9
Total weight of train uphill, one locomotive	226½ tons
" " " " downhill "	510 tons.
Total time for round trip without layovers or switching	144 minutes.
Schedule time for round trip	3 hr.
Round trips per locomotive per day	4
Ton-miles per round trip	15,800
" " day—8 round trips	126,400
" " switching	6,500
Kilowatt-hours per day at locomotive	6,110 kw-hr.
" " " " from high-tension bus	9,050 kw-hr.
Ave. load per day of 12 hrs. from transmission system	754 kw.

Three locomotives are required for this service, two main line and one for switching.

With 1200-volt electrification, two 500-kw. substations will care for the power demand. The total approximate cost of the locomotives, substations, transmission line, overhead, bonding and feeders is $190,000.00.

For similar operation with oil-burning locomotives, two 125-

ton standard slow speed freight locomotives and four 50-ton geared type locomotives are required, and even with this equipment the train must be broken at the heaviest grade, necessitating a return trip for a portion of the empty train which starts from the terminal.

The locomotives burn oil fuel, which costs approximately $1.15 per barrel for main line locomotives and $1.20 per barrel for switching locomotives at the logging camps. Electric power can be purchased for 0.9 cent per kilowatt-hour net.

The following table of maintenance and operation, omitting those items which are approximately the same under the two conditions, shows a net saving of $20,068.00 per year with the electric railway:

	ELECTRIC	STEAM
Interest and depreciation	$19,000	$ 9200
Maintenance	7168	10,436
Wages	10,200	21,300
Power or fuel	24,500	38,500
Supplies	1500	3000
Total	$62,368	$82,436.

Under "electric operation" the different charges cover both substation and train operation. There are some items which ordinarily would favor electric operation—for instance, track maintenance has been considered the same in both cases and omitted from our consideration, since in logging railway operations the greatest damage to the tracks appears to come from the swaying of the loaded cars, and not from the locomotives.

With steam operation, 84½ bbl. of oil were used per day for main line haulage for the two 125-ton freight locomotives, and two 50-ton shays, and 22.3 bbl. per day for the two 50-ton switching locomotives. In this present instance the steam locomotives are taxed to their utmost capacity while logging operations are being carried on at the near end of the timber holdings.

It will be necessary within a few years for this road to be extended approximately twelve miles further, the prevailing grade on the extended line being the same as at present, and an analysis of the future conditions will show that four locomotives operating thirteen hours each per day will be able to care for the output and the conditions will then be very much more favorable for electric operation.

Milling

Under the first heading will come all that part of the manufacturing plant which converts the logs into timbers or boards, including all operations—from taking the log from the pond until the rough manufactured product is sorted into its various dimensions and lengths, ready for storage or further manufacturing. These operations may be divided into the following branches: handling the logs: sawing: trimming and sizing: disposing of refuse: sorting: storing or shipping.

In order that the sawmill operator may more profitably dispose of his better grade stock, a finishing mill is a necessity and in reality such a more or less completely equipped mill is always understood to be included in the general term "sawmill". The operations are so distinct, however, that it has been thought best to include the planing mill under a separate heading.

In those mills which finish a large portion of their product, there is between the sawmill and planing mill a seasoning process, which we will term "treating". This consists of artificially drying the product before finishing it. Its object is to get the material to its ultimate seasoned dimensions before the final manufacturing operation. Those operators who must overcome the handicap of high freight rates secure an additional advantage in eliminating all excess weight due to moisture. Some specialty mills (shingle mills, for instance) resort to drying solely for the purpose of reducing weight.

The treating process includes: stacking: drying: unstacking: sorting.

For economy of space, the material must be stacked in some uniform manner; industrial type flat cars are generally employed, with mechanical means for loading the lumber upon these cars. With the old method of hand stacking, the capacity of two men per day seldom exceeded 10,000 ft. b.m., which is approximately 2000 boards.

When the electrically operated stacker is used, the boards are taken directly from the sorting chain and two men can care for from 45,000 to 50,000 ft. per day. The lifting arm of this equipment, which lifts each stack in position, together with a short section of the conveyer table, is operated by a $7\frac{1}{2}$-h.p. motor, belted to a line shaft and running continuously. The load factor is not more than 5 per cent. The peak when lifting the arm is approximately 12 h.p., while running the mechanism light requires 2 h.p.

The dry kilns universally follow the old principle of steam radiator construction. The steam legs of the radiator are made up of a large number of small pipes, one in. (2.54 cm.) to 1½ in. (3.81 cm.) in diameter, which run the length of the kiln and connect to steam exhaust headers at the end. A typical dry kiln layout is shown in Fig. 9. It is common practise to admit high-pressure steam directly to the pipe. Of late years the vacuum system, taking exhaust from the mill engines at 5 to 30 lb. (2.2 to 13.6 kg.) gage and exhausting into 20 to 25-in. (50.8-to 63.5-cm.) vacuum, has come into rather general use. Where high-pressure steam is used directly, a reducing valve which cuts the pressure to approximately 50 lb. gage is ordinarily inserted.

It requires about 72 hours for drying planing mill stock, and six days for drying bundles of shingles. After the kiln has once reached a constant temperature approximately 1000 lb. (453.5 kg.) of steam per hour are required by the average kiln.

In green lumber, 30 per cent to 40 per cent of the weight is moisture. The dry-kiln operation reduces this to from 6 per cent to 10 per cent after drying. The process is not carried further as there is no necessity of furnishing lumber drier than the air at the locality in which it is to be used.

After drying, the lumber is unstacked and distributed to the finishing machines. The scheme for unstacking edge-piled lumber in most common use consists of an endless chain with hooks spaced about 10 ft. apart, running in vertical guides, these guides at the top being curved to direct the boards on to a conveying table. As the hooks revolve, they engage the bottom of the stack, lifting it from the car, and the top guides direct to a transfer table, from which it goes to the sorting table and is classified and taken to the finishing machines. This unstacking device is driven by a 5-h.p. constant-speed motor and requires approximately 4 h.p. while lifting the stack and 1¾ h.p. running the lifting and conveying chains only. Its unloading capacity is approximately 60,000 ft. b.m. per day.

Planing Mill

Operations in this mill consist of planing or finishing the stock, trimming, disposing of refuse, sorting, tying or bundling, and storing or shipping.

The product of this mill comprises the highest grade lumber and is consequently given close attention.

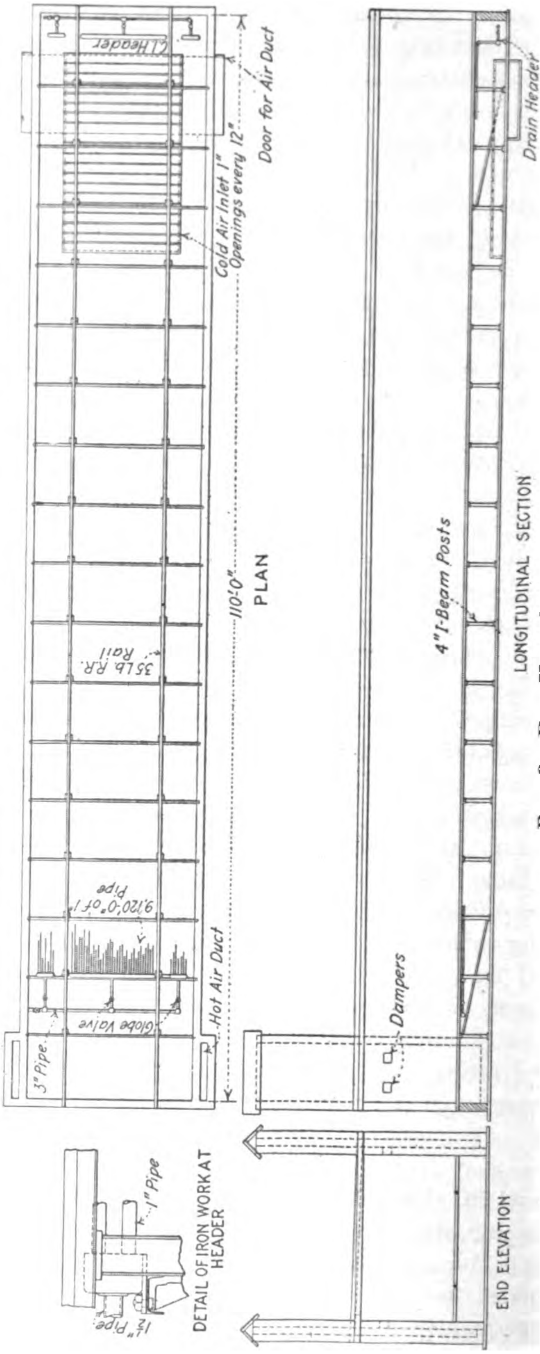


FIG. 9—DRY KILN LAYOUT

Before planing, it is often necessary to do a small amount of re-saw work, but this is of a very light character, its purpose being to re-manufacture yard stock to supply the accumulation of orders for any one size of lumber. The refuse from this mill is the best fuel supply, since it is thoroughly dry.

Specialty Mills

Specialty mills are often valuable adjuncts in utilizing materials which would otherwise be thrown away as refuse. Very often they have no connection whatever with sawmills and must purchase their material in the open market. In the following, therefore, we have considered only those specialty mills which have a direct connection with sawmills.

Lath Mills

Lath mills are always run in connection with sawmills and obtain their material from slabs and edgings which would otherwise go to the refuse burner or, at best, to the wood bins. The slabs are taken from the main refuse conveyer and go through the following processes: bolter: lath machine: trimming, bundling.

Bolting consists of sizing the slab to the dimensions necessary for putting through the lath mill. The bolter may consist of a number of saws, therefore making several bolts at one operation, and requires about 7½ h. p. per saw.

The lath mill consists of three saws, making four laths of each bolt, and requires approximately 25 h. p. The laths are then trimmed to 4-ft. (1.21-m.) lengths and tied in bundles of 50 or 100, after which they are ready for storage or shipment.

Saw Mills

In saw mill operations the work consists essentially in manufacturing a log to boards or timbers of a certain thickness, width and length, so in its elementary form only three machines to perform these functions are necessary. In the following, therefore, we will follow the progress of the work through the mill in its simplest form, afterwards returning to the auxiliary machines which have come as a natural result to increase production by performing some of the elementary functions faster or with greater facility than could be done with only the major machines.

In driving the mill machinery, squirrel cage motors are used

wherever possible, because of their simplicity and strength. Unless specifically noted to the contrary, it will be understood that constant-speed, alternating-current induction motors are referred to. Practically all of the work is at constant speed, and in fact in sawing operations this is of prime importance. In the first installations, individual drive for each device or machine was used without question, thus, at one step, past practise with line shaft and belting, with all group drives, was entirely reversed, in an endeavor to do away with shafts, belts and transmission machinery entirely. Today, semi-group drive is standard. All parts which work to the same end and are close together, are grouped. Groups usually embrace such devices as transfer rolls, transfer chains, conveyers, etc., which require a certain amount of transmission machinery in any event, and which require practically the same power when running idle as when working. The milling machines themselves are individually driven.

The power demands of the machines fluctuate so that it is practically impossible to plan for other than the maximum demand which might be encountered. For instance, an edger may run on narrow material with two saws cutting a two-in. board, and within five minutes, the same machinery may be called upon to handle a 6-in. (15.24-cm.) to 12-in. (30.48-cm.) cant, requiring four or five working saws, taking in the first place approximately 40 h. p. and in the second place 350 h. p.

In the following, wherever load factor is given, it is taken as load factor based upon the time of a working day. Some mills operate 24 hours, while others run 10 hours, and it is therefore obvious that unless the actual working time for each day is taken, the data will not apply universally.

Fig. 10 gives the general plant and yard scheme of a modern Pacific Coast mill. The logs as delivered to the pond are of various lengths and sometimes must be cut to accomodate the mill layout. This operation is performed more often when the logs are still in the water, but is sometimes done after they have been lifted to the log deck. Fig. 11 shows the saw used in the latter way. The driving motor is a squirrel cage type, 10 h. p., and is run intermittently. Its load factor is not greater than 6 to 7 per cent.

Log Lift

The logs are carried from the pond either by the old arched log haul, or by the later log lift (Fig. 12). In the first case an endless

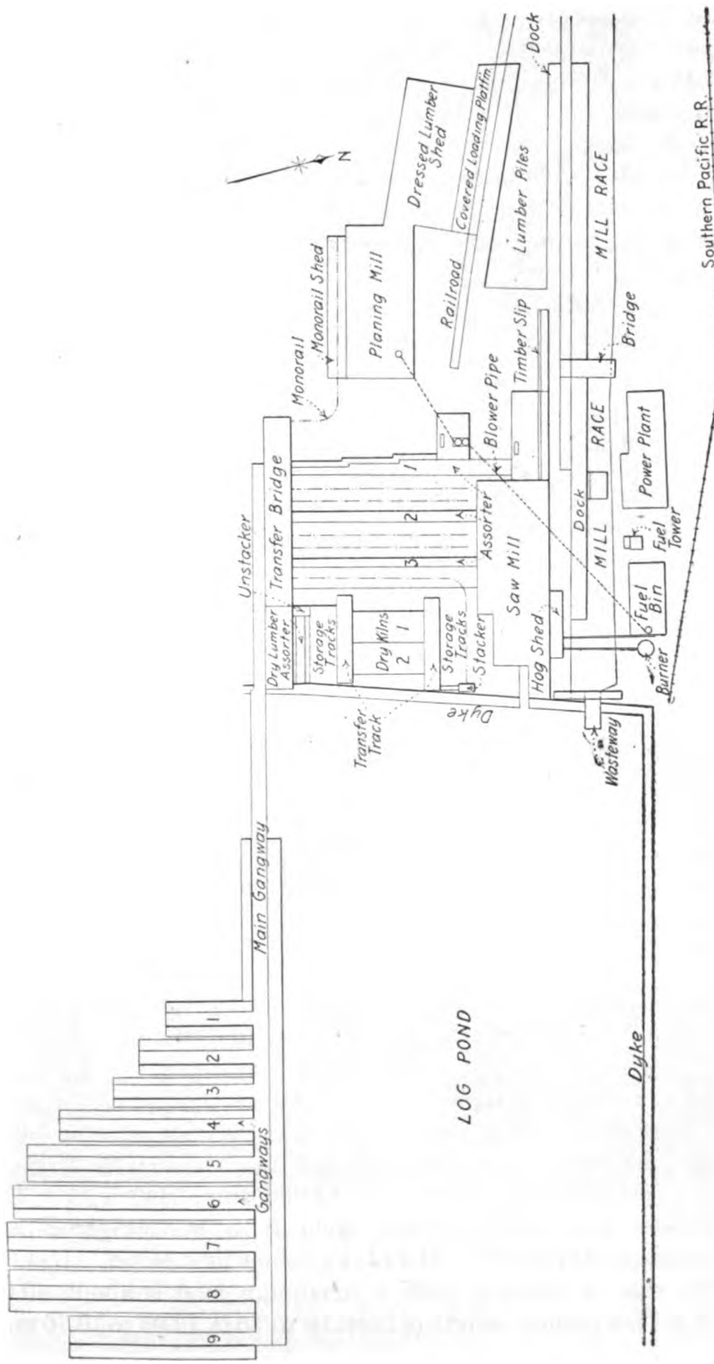


FIG. 10—YARD LAYOUT—BOOTH-KELLY LUMBER COMPANY

chain with hooks spaced several feet apart runs in a groove in the arched log haul structure, at a speed of approximately 50 ft. (15.25 m.) per minute. The driving sprocket is driven by a constant-speed squirrel cage induction motor of about 35 h. p., through the necessary speed-reducing transmission machinery. See Fig. 13. The motor runs continuously and the load is thrown on or off by the friction device. The log lift is coming into more general use, because of the upkeep expense of the older scheme of log haul.

A canal leading from the log pond is built into the head end of the mill, paralleling the log deck. Cables are attached to the edge

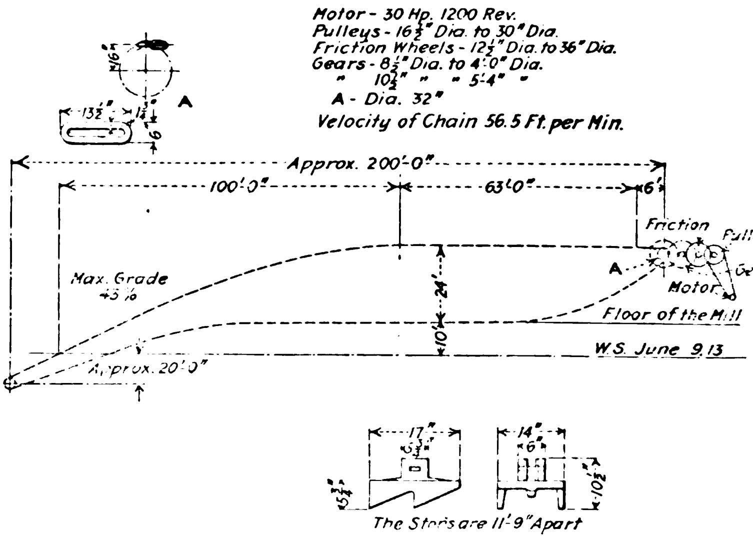
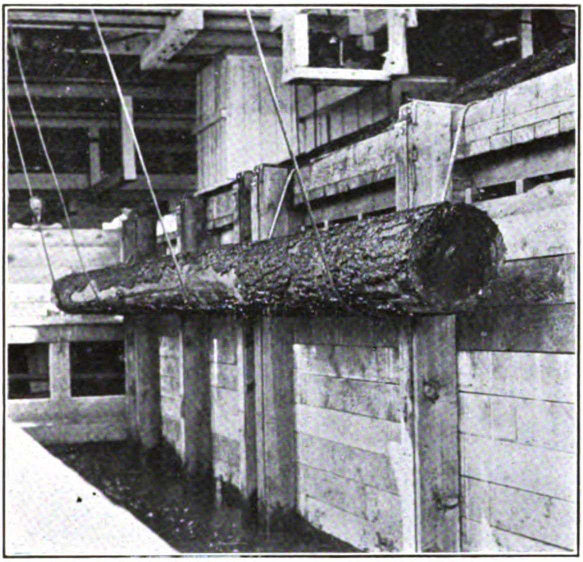


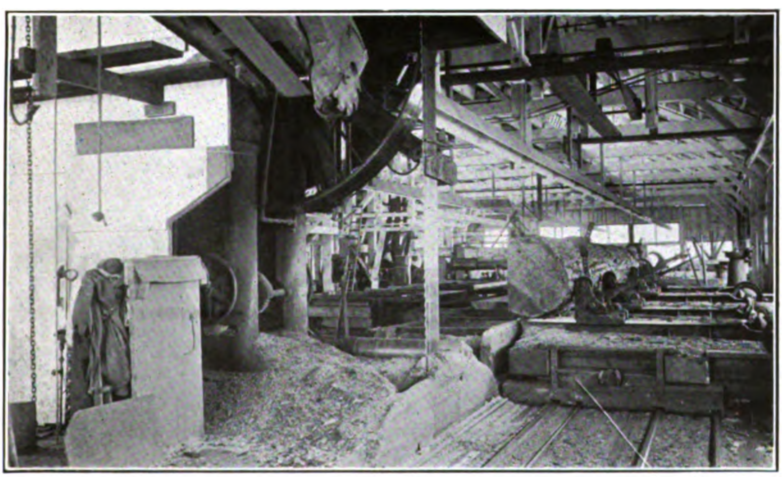
FIG. 13—LOG HAUL

of the log deck and fixed to hoisting drums overhead, allowing the loop to fall below the surface of the water in the canal. The logs are floated in and then hoisted, the natural angle of the cable as it becomes taut at the end of travel rolling the logs on the deck. An intermittent-duty hoist-motor, with reversible controller, drives the mechanism. The average load hoisted is 1500 ft. b. m., weighing approximately 12,000 lb. (5443 kg.). The maximum will hardly exceed 6000 ft. b. m., weighing approximately 48,000 lb. (21,772 kg.).

The rate of hoisting with a maximum load is about 40 ft. (12.1 m.) per minute; length of hoist 10 to 35 ft. (3.05 to 10.76 m.).



[WHITNEY]
FIG. 12—LOG LIFT WITH LOG AT HALF ELEVATION



[WHITNEY]
FIG. 15—TEN-FOOT BAND HEADSAW AND LOG CARRIAGE AT END OF TRAVEL. BOARD WHICH HAS JUST BEEN CUT IS LYING ON LIVE ROLLS

Common practise requires 37 to 52 h. p., depending upon the character of the logs handled. The load factor is approximately 6 per cent. See Fig. 14, showing a cross-section of the head end of a sawmill at the head saw.

The adjuncts of a log deck, viz: "kickers" and "niggers," used for turning the logs and pushing them on the carriage, as well as the log carriage itself, are usually steam-operated. These devices are uneconomical steam users, but their demands are not very great and they are very seldom a source of additional cost in boiler plant capacity.

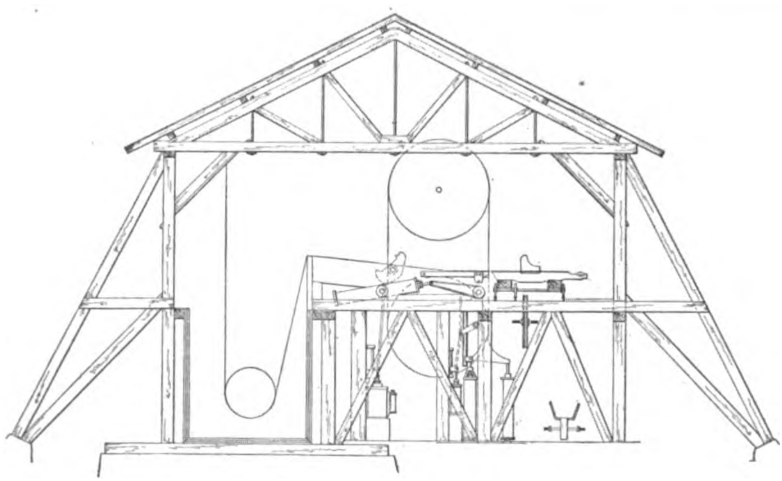


FIG. 14—SECTION AT HEADSAW

The duty of the log carriage, Fig. 15, is very severe, as may be noted from the following typical cycle:

Average speed during cut	250 ft, per min.	(86.25 m.)
" " of return (assuming single cutting mill)	650 " " "	(198.25 m.)
Total distance of travel one direction	20 to 60 ft.	(6.1 to 18.3 m.)
Average weight of carriage and log of 1500 ft. b. m.	38,000 lb.	(17,237 kg.)
Maximum speed during cut	350 ft. per min.	(106.75 m.)
Minimum speed during cut	100 ft. " "	(30.5 m.)

From these we see that the retardation at the end of travel and the acceleration of return must be at very high rates in order to lose a minimum of productive time.

The log after each cut must be moved up a definite amount in preparation for the next cycle. This is accomplished by the set works. A five-h. p. constant-speed induction motor mounted

on the carriage and running continuously provides the simplest means of driving this device.

With direct current available, a series motor will prove more economical in energy consumption and will run only when the set works is operating. Current is collected from protected trolleys or from a loop cable supported by rings carried on a rod attached to the side of the building. A back-geared motor or one fitted with silent chain drive proves most compact. The control mechanism must be arranged for reversing operation.

The canting gear, usually driven by a 15-h.p., constant-speed motor, is required only when a very irregularly shaped log is encountered. It consists simply of a drum with attached hook

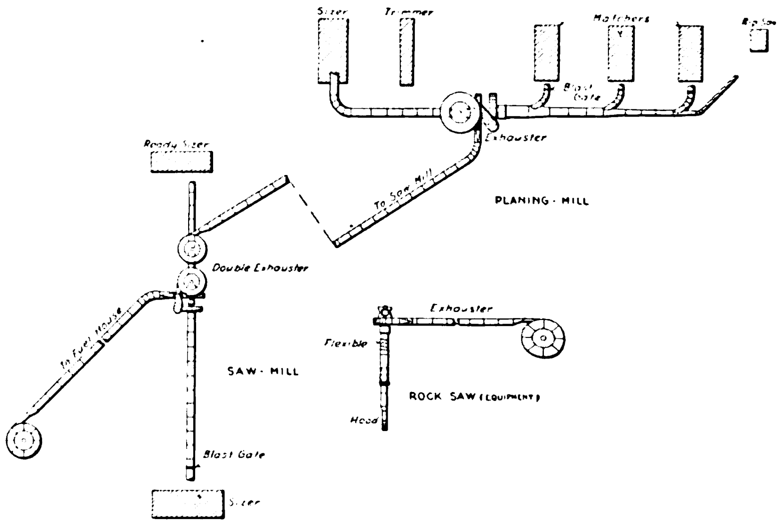


FIG. 16—REFUSE EXHAUST SYSTEM

and cable for turning the log on the carriage. This operation is now performed by power machinery in all except the most extreme cases. The motor operates so intermittently that its energy and power requirements are of little interest.

ROCK SAW

A small saw ordinarily known as a "rock" or "barking" saw, to remove gravel, barnacles or other foreign matter from the bark of the log, usually precedes the main saw in the line of cut. It operates continuously, and requires a 15-h.p. motor; its load factor is approximately 30 per cent. A tin housing, piped to an exhaust fan, allows the dust to be carried away. This fan

requires 15 h.p. and runs continuously at constant speed, with a load factor of approximately 100 per cent. See Fig. 16.

Head Saw

The essential duty of this saw is to cut timbers of a certain thickness from the log. Refinements of this process—*i.e.*, reducing these timbers to boards—really fall to other machines, viz., re-saws and gang saws, because of operating requirements. The single-cutting band mill is by far the most popular type of head saw; double-cutting mills are in general use when handling smaller timbers than are common in the Pacific Coast country, but circular head saws are by no means obsolete.

A typical 10-ft. (3.05-m.) single-cutting band mill is shown in Figs. 15 and 17. Driving this is a 300-h.p. constant-speed motor with wound rotor, and provided with drum controller and resistance for starting duty only. The large inertia of the heavy saw tension and driving wheels imposes severe starting conditions, but once up to speed, helps greatly in equalizing the load, so that in running we seldom encounter very high peak demands. The following data are typical of a mill of this capacity:

Speed of saw wheels	300 rev. per. min.
Running demand range	230 to 450 kw. input
Starting demand	560 kw. input
Duration of starting demand	38 seconds
Running light, input	60 to 70 kw.
Average kw-hr. per day of 10 hr.	1050
Load factor—average*	22 per cent

Because of the slow speed of large band mills the motor is usually belted and a belt tightener used. See Fig. 18. Three-bearing motors are universal practise.

The polar-wound rotor type for constant speed service is commonly used, to limit the current input at starting. Where ample station capacity is available a squirrel cage motor can be used with impunity, now that the electrically-welded rotor end-ring construction has so greatly increased its ability to withstand long-sustained starting periods without damage. The simplicity and strength of a squirrel cage type motor makes its use very desirable.

With double-cutting mills the load factor and daily kilowatt-hour consumption are higher than the values given above. The power per thousand feet, however, is lower, due to the greater proportion of working to idle periods.

*In this instance, as in the others cited, the load factor may not agree exactly with the performance figures given—all figures are averages of a large number of tests and are indicative of average performances only.

Circular Head Saws

Squirrel cage motors are universally used for circular head saws. The inertia of the circular saws is low and the load fluctuations during the cut must be taken care of entirely by the motor. Fig. 19 shows a motor driving a double circular 66-in. (1.68-m.) saw. Where the saw speed permits, the best practise is to connect the motor directly to the lower saw arbor, driving the top saw with a belt. The following operating data are typical of a large double circular head saw:

Running demand range	240 kw. to 560 kw. input
Starting demand	360 kw. input
Duration of starting period	15 seconds
Running light	35 kw.
Average kw-hr. per day of 10 hr.	1150
Load factor, average	20 per cent

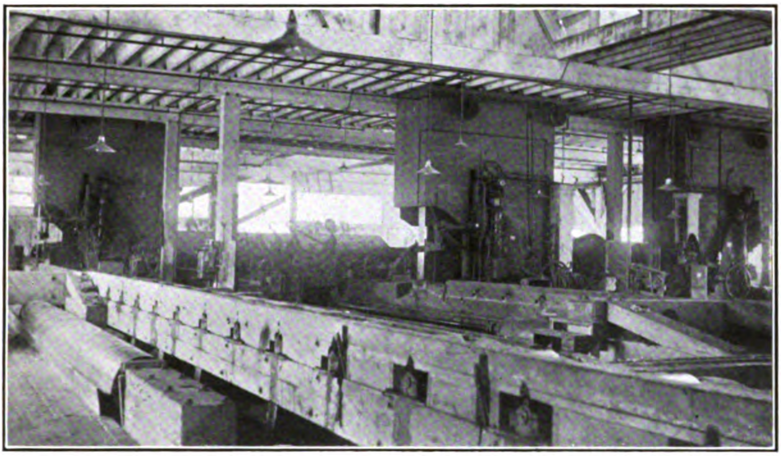
From the head saw, the boards or cants are conveyed by rolls and transfer chains which distribute the product to the other machines (Fig. 20). The rolls directly in front of the head saw run at speeds of about 350 ft. (106.7 m.) per minute, the speeds in later sections decreasing slightly.

Present practise leans toward grouping two sections of roll with one or more sets of transfer chain, driving the group from a countershaft operating at 900 rev. per min., and driven by a direct-connected, constant-speed, squirrel cage motor. All rolls must be arranged for both forward and reverse operation, and the simplest scheme for accomplishing this and at the same time relieving the motor of all starting demands, requires the use of friction devices.

With individual motor drive, a back-geared reversing motor with chain drive from the back-geared shaft provides the most compact arrangement. Such a motor should preferably be of the polar-wound rotor type. Fig. 21 shows a general scheme using group drives.

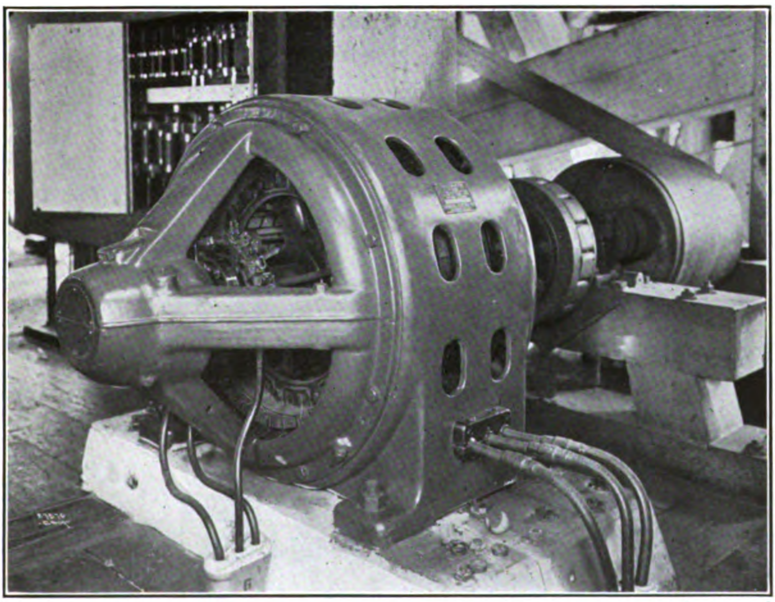
Live rolls 12 in. (30.48 cm.) diameter by 30 in. (76.2 cm.) long require approximately 0.4 h.p. per roll when operating at 200 rev. per min. When operating at 100 rev. per min. they require approximately $\frac{1}{4}$ h.p. per roll. As a typical group, a section containing eighteen 12-in. by 30-in. (30.48 by 76.2-cm.) rolls at 120 rev. per min. and thirteen 12-in. by 30-in. (30.48 by 76.2-cm.) rolls at 80 rev. per min., three slab transfer chains, and three edger transfer chains, requires seven kw. input.

As an example of individual motor drive, with back-geared motor and chain drive to one roll case containing fifteen 12-in.



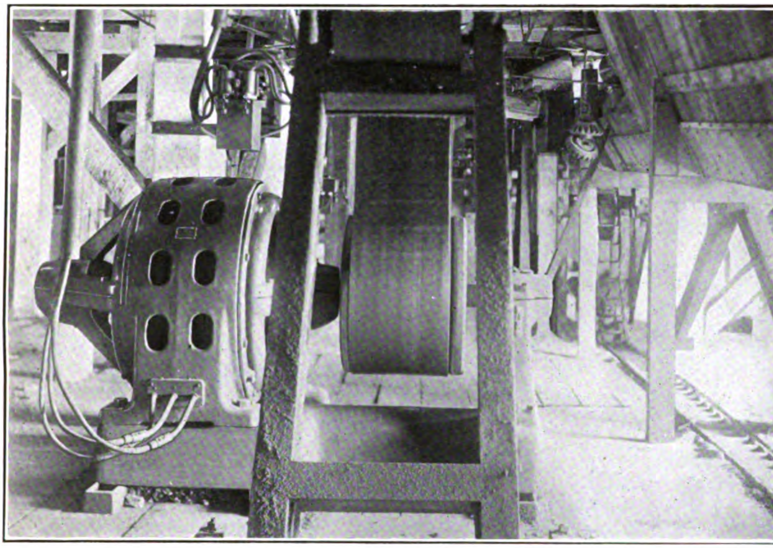
[WHITNEY]

FIG. 17—MILL FLOOR, SHOWING THREE NINE-FOOT BAND HEADSAWS



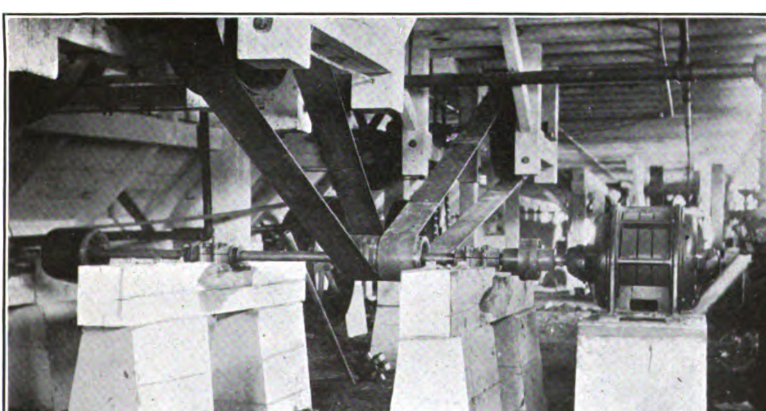
[WHITNEY]

FIG. 18—300-H. P. MOTOR DRIVING 10-FT. BAND SAW IN PACIFIC COAST MILL



[WHITNEY]

FIG. 19—250-H. P. SQUIRREL CAGE MOTOR DRIVING DOUBLE 66-IN. CIRCULAR HEADSAW IN PACIFIC COAST MILL



[WHITNEY]

FIG. 20—TYPICAL GROUP FOR DRIVING TRANSFERS, LIVE ROLLS, ETC.

by 32-in. (30.48 by 76.2-cm.) rolls driven from a line shaft by bevel gearing, the maximum running load is 4.8 kw. and the average running load is 3.7 kw. This information applies to cases where rolls are well lubricated and gearing in first-class shape. No average conditions can apply generally, since by far the greater part of the load is due to friction.

Edger

The function of this machine is to cut the stock to width after it has been cut to a predetermined thickness by the head

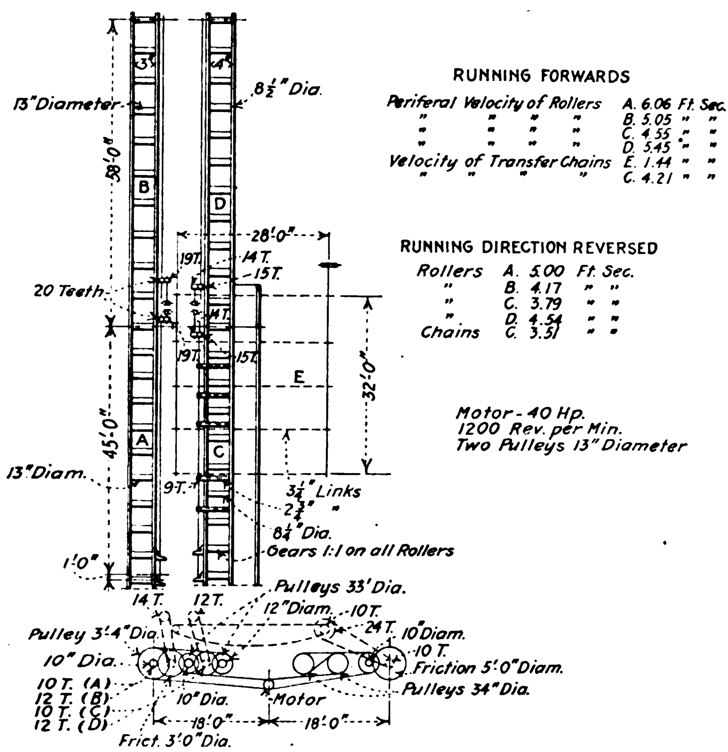


Fig. 21—Grouping of Live Rolls and Chains Driven by One Motor

saw. It therefore consists of a number of circular rip saws, with the position of each adjustable on an arbor, the total width of stock determining the number of saws working at any one time and their position. See Fig. 22. Edgers adapt themselves admirably to direct connection; their speed is high and saw sizes can be so chosen as nicely to fit a 1200- or 1800-rev. per min. motor, which speeds are suitable for direct connection.

The starting load is comparatively light; the running load fluctuates through wide ranges and the saw speed should be practically constant, which conditions have caused the squirrel cage, constant-speed induction motor to be universally adopted. The feed rolls should be reversible, and capable of having their speed adjusted (see Fig. 23), the rate of feed depending upon the stock and varying from 325 ft. (99.1 m.) per minute to 120 ft. (36.6 m.) per min. For driving these rolls the latest practise has adopted a varying-speed, constant duty, reversing motor with polar-wound rotor.

On the edger arbor are mounted from five to seven saws running at rim speeds of 9000 to 12,000 ft. per minute. The

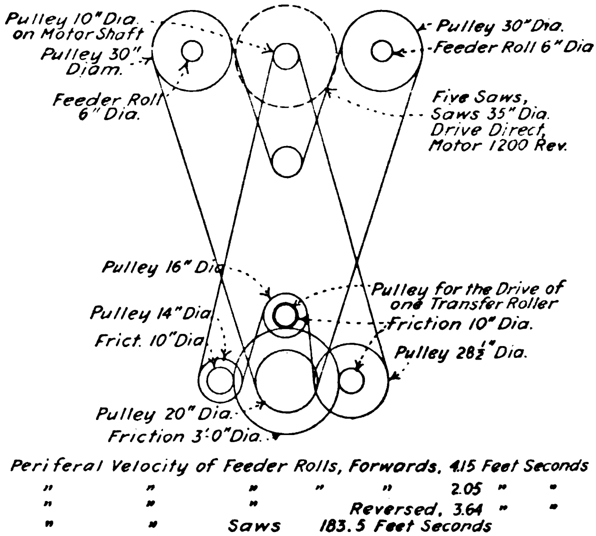


Fig. 23—Feeder Roll Drive

following is typical of the demands of a Pacific Coast edger 12 in. by 72 in., eight saws direct-connected to a 200-h. p. 1200 rev. per min. squirrel cage type motor:

Input—idle	35 kw.
—5 saws cutting 6 in. stock @ 220 ft. per min.	350 "
—5 saws cutting 6 in. stock @ 135 ft. per min.	247 "
—3 saws cutting 10 in. stock @ 135 ft. per min.	290 "
—4 saws cutting 2 in. stock @ 230 ft. per min.	75 "
—6 saws cutting 1½ in. stock @ 240 ft. per min.	75 "
Average per 10 hr. day	405 kw-hr.
" load factor	11.6 per cent.

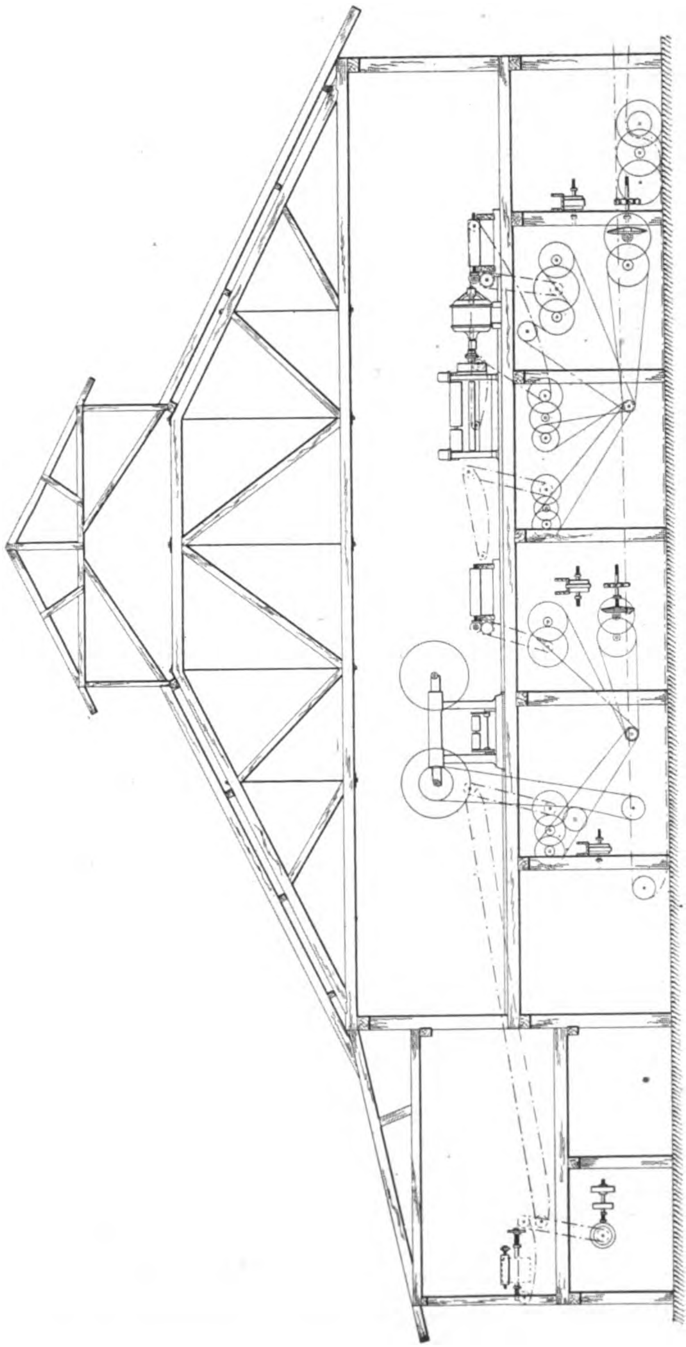


FIG. 24—SECTION AT EDGER AND RE-SAW

TRIMMER

This appliance cuts rough stock to length. It consists of a gang of circular saws arranged in a horizontal line and spaced two feet apart, the total length varying from 40 to 50 ft. (12.2 to 15.25 m.). See Figs. 25 and 26. There are rarely more than four or five saws working at any one time and the load demand lasts only for an instant, so that by far the greater part of the energy is consumed in running the saws idle. The speed of the saws is of course constant, and operating constantly the load factor is 60 to 70 per cent. The saws are belted to a main drive shaft

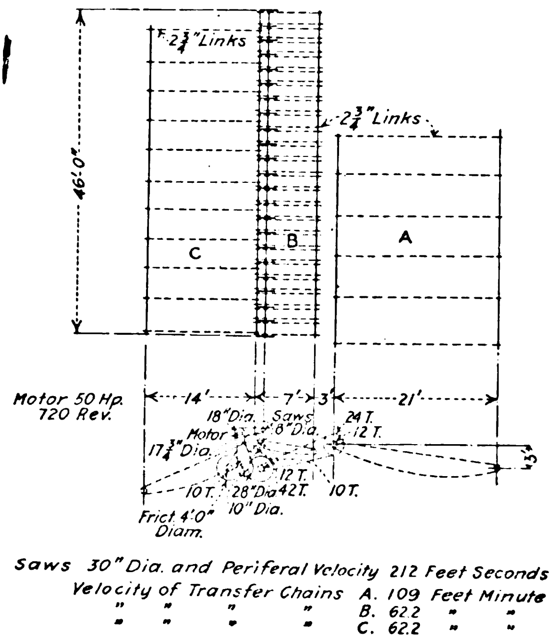


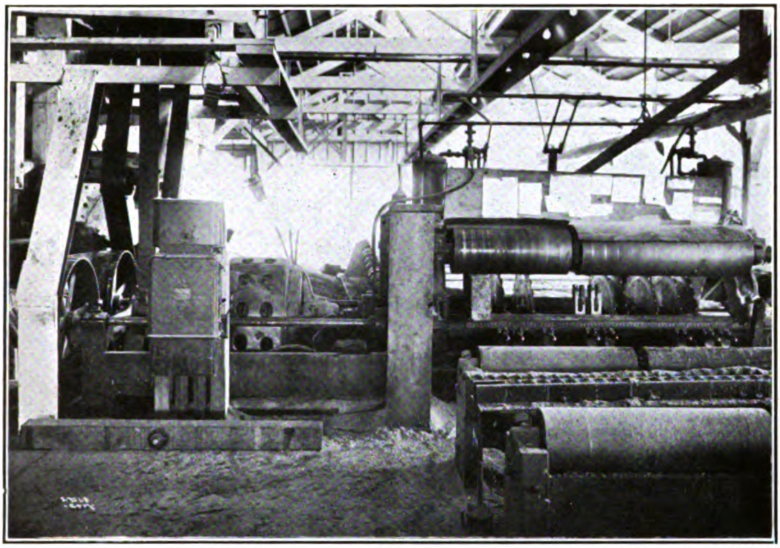
FIG. 26—TRIMMER

which in turn is driven by a direct-connected, constant-speed, squirrel cage motor. For average conditions, 50 h.p. suffices. The following observations give the operating requirements, including transfer mechanism:

Running demand range when cutting	47 to 80 kw.
Starting demand	70 kw. input.
Duration of starting	18 seconds
Running light, input	29 kw.

SORTING TABLE

From the trimmers, the stock passes over chain conveyers spaced 4 ft. (1.22 m.) apart, to the sorting table, where it is graded

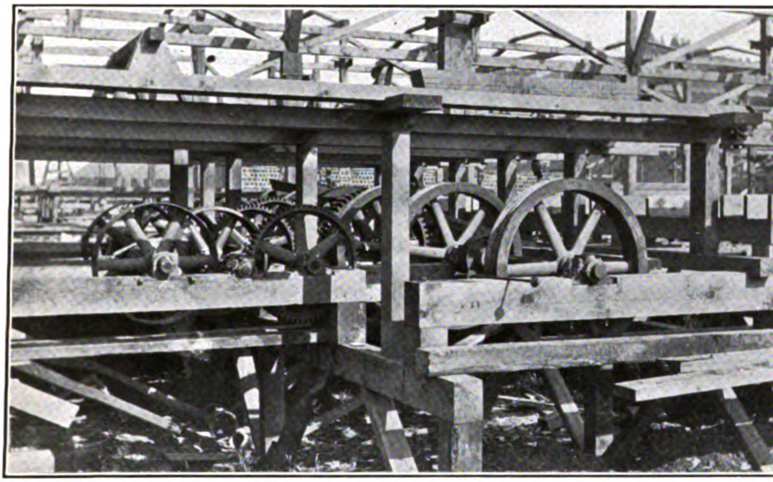


[WHITNEY]

FIG. 22—200-H. P. MOTOR DIRECT-CONNECTED TO 12½ BY 84 IN. EDGER HAVING EIGHT SAWS

[WHITNEY]

FIG. 25—FRONT OF 40-FT. TRIMMER REQUIRING A 50-H. P. MOTOR



[WHITNEY]

FIG. 27—TRANSMISSION FOR SORTING TABLE. DRIVE RATIO 900 TO 1

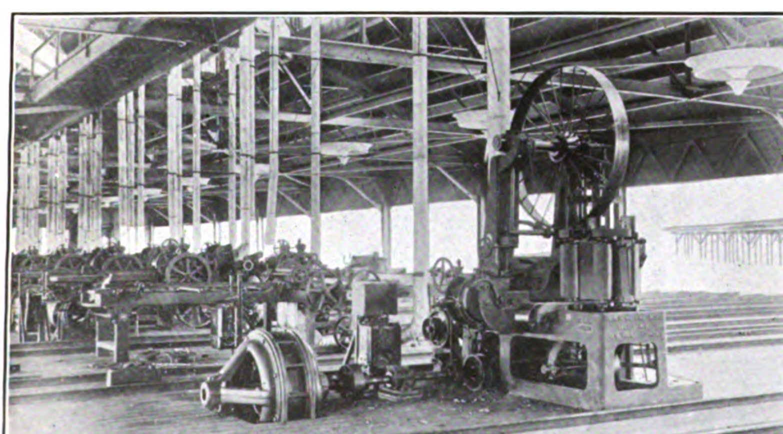


FIG. 28—BAND RE-SAW WITH DIRECT-CONNECTED MOTOR [WHITNEY]

and removed for placing in yard stock, treating in the dry kilns preparatory to further finishing, or to be returned to the mill for further reworking.

The sorting table consists of several chains or cables running at about 15 to 30 ft. (4.58 to 9.15 m.) per minute. The starting requirements are heavy, since the mass to be accelerated is very large. A friction device is invariably placed in the speed-reducing transmission machinery, however, which relieves the motor from all starting strains and allows a squirrel cage type motor to be used for the drive.

The motor is semi-exposed to the weather, and in its manufacture, this fact should be considered. The running load is fairly light and practically constant. A motor with polar-wound rotor, back-geared shaft and chain drive from back-geared shaft direct to table driving sprocket, will eliminate all of the transmission machinery shown in Fig. 27. This scheme has not met with general success, however, due to the very severe starting strains as compared with the running load. The table itself should be of such length that sorting for both dimensions and lengths can be accomplished without too great congestion at its end. The power requirements for an average case are about as follows:

Motor, 10 h. p. back-geared 850 to 128 rev. per min.
Chain drive from back-geared shaft.
Drives 1596 ft. No. 75 chain—Chain weight 3445 lb.
Lumber per hour—12,000 ft. b. m.
Speed of first section 35 ft. per min.—decreasing to 29 ft. on last section.
Maximum noted load running........................7.5 kw.
Average load running...............................5 "

Re-Saws

These machines re-work stock which has not been cut to its ultimate thickness at the first operation. Fig. 28 shows a six-inch vertical re-saw which is direct-connected to a 75-h.p. motor. The starting duty is heavy, due to the weight of the lower wheel and the inertia to be overcome. It is therefore common practise to use a squirrel cage motor with substantial end-ring construction and resistance rotor. When running, the tension wheels serve as an equalizer, reducing the peak demands. The feed rolls are sometimes operated by an individual motor, and in a re-saw of this size, approximately 10 h.p. is required for them, the feed roll motor being a standard squirrel cage machine.

The following are typical service data of a heavy-duty band re-saw:

Rate of feed	185 ft. (56.4 m.) per min.
Splitting, 2 in. (5.08-cm.) by 12 in. (30.48 cm.)	80 kw. input
4 in. (10.16 cm) by 10 in. (25.4-cm)	60 " "
Running light	16 " "

Horizontal re-saws are becoming more popular because of the ease with which they may be instantly adjusted to care for stock of different dimensions. Such a machine can, for instance, handle on one side of its adjustable bed a 6 in. by 12 in. cant, re-sawing to 4 in. by 12 in. and 2 in. by 12 in., and on the other side at the same time re-work a 2 in. by 8 in., making two 1 in. by 8 in. boards. The starting duty is about the same as for the vertical type. The running load fluctuates no more widely.

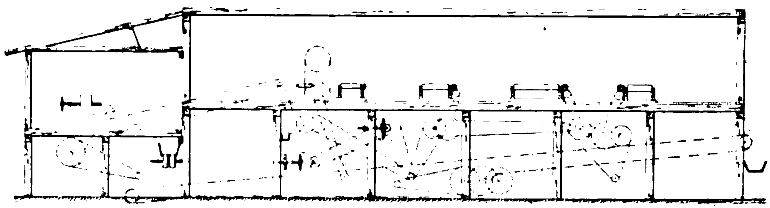


FIG. 31—SECTION OF RIPSAW

GANG SAWS

Gang saws, as the name implies, consist of a number of straight crosscut saws which split a cant at one operation into a great number of boards of the proper thickness. The boards then proceed to the trimmer and are cut to length, as with the output of the edger. These saws have a vertical reciprocating and oscillating motion and the machine is equipped with a flywheel to equalize the load. The average size gang requires a 75-h.p. motor.

A rip saw, Figs. 29 and 30, is required to reduce the width of a certain amount of the mill run, according to order demands. Fig. 31 shows a rip saw, rolls and transfer to rip saw from first section of sorter chains. A silent chain drive or a direct-connected motor may be used. Either method operates satisfactorily, the particular drive adopted depending on the mill layout and space available.

Rough timbers often require no further sizing work than can be performed by the head saw, and never more than an additional passage through the edger. They are conveyed directly to the

tail end of the mill, where the ends are squared by a large cross-cut saw—and then proceed to the loading platform. Sometimes, however, for uniformity of alignment in building operations one or more sides must be planed after the timbers have been squared at the end, and consequently they go to what is known as the "green" mill. This consists of one or more planing machines, with an exhaust fan to dispose of the shavings. The planers ordinarily used for this work are known as "ready sizers," a machine which is quickly adjustable for different size timbers and is arranged to surface only an edge and a side, and "timber sizers," which ordinarily have four cutting heads and can surface all four sides of the stock. The average power requirements of such a machine are as follows:

TIMBER SIZER

Size stock	Feed	Sides sized	Input Kw.
5-in. by 5-in.	60 ft. per min.	4 sides	Avg. 33.2 Max. 41.1 Min. 29.1
2 by 12 in.	125 ft. " "	4 sides	Avg. 46.2 Max 71. Min. 43.

READY SIZER

Size stock	Feed	Sides sized.	Kw. Input
2-in. by 12 in.	96 ft. per min.	side and edge	Avg. 38.2 Max. 50.1 Min. 31.9
2 by 4 in.	96 ft. " "	" " "	Avg. 31.4 Max. 35.6 Min. 26.5

For transferring cants from the main rolls past the head saw to the storage platform in front of the gang saw, an overhead crane transfer is provided (shown at top of Fig. 32). The hoisting and propelling motors are series-wound, direct-current machines, and are supplied from a motor-generator set.

REFUSE

The refuse from the various sawmill manufacturing processes consists of dust from the saws, edgings, trimmings, and shavings from the "green" planers. Figs. 33 and 34 show conveyer drives. V-shaped troughs in which chain and block conveyers run, serve to handle the sawdust from the main mill machines, but from the planing machines the shavings must be carried

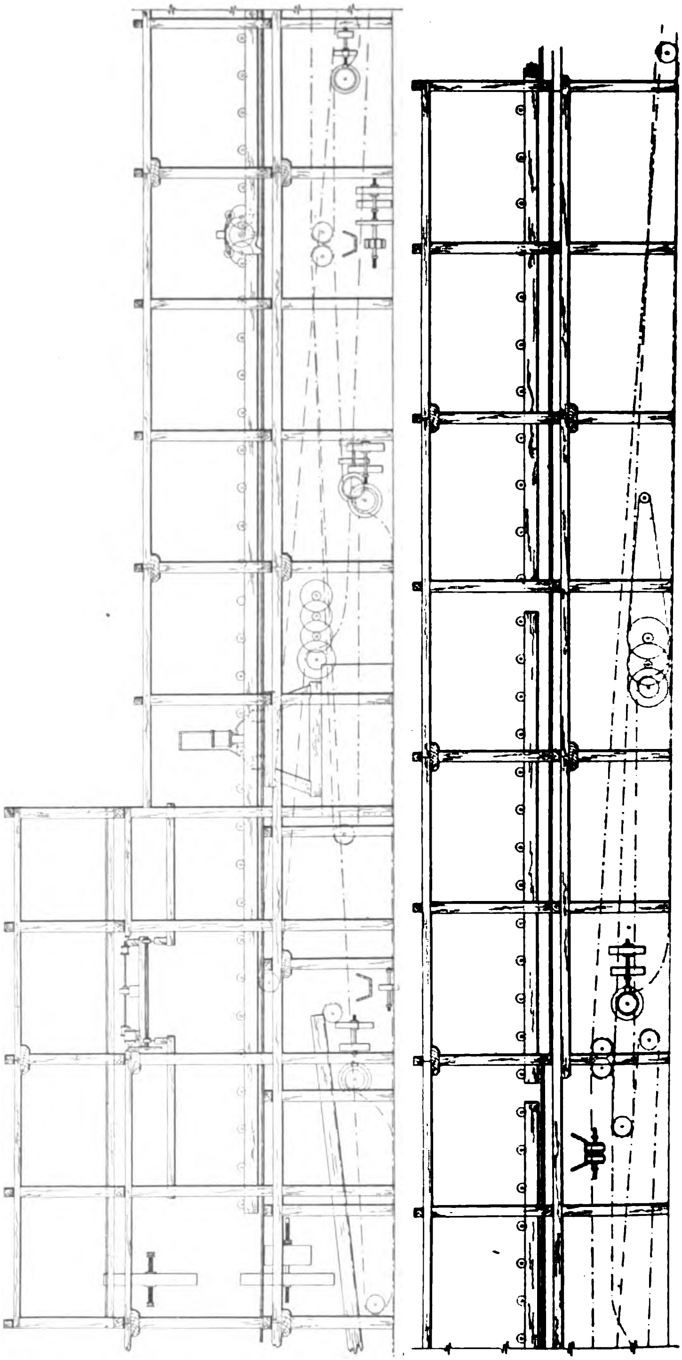


Fig. 32—Side Elevation of Mill

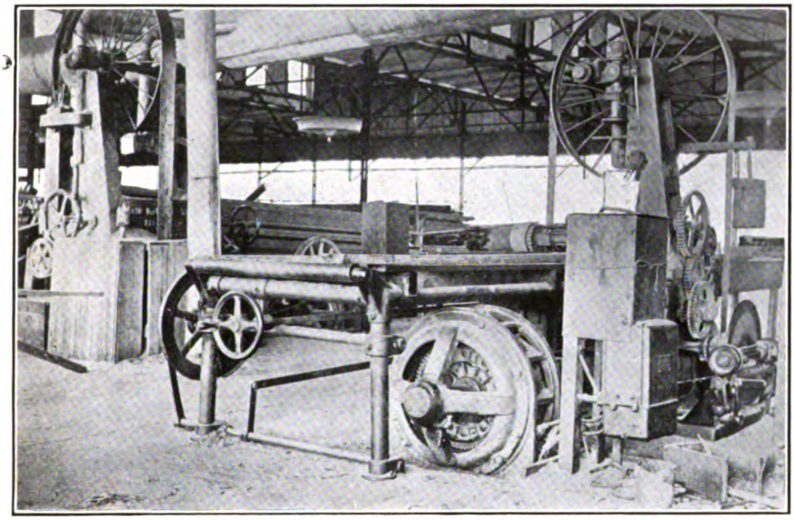
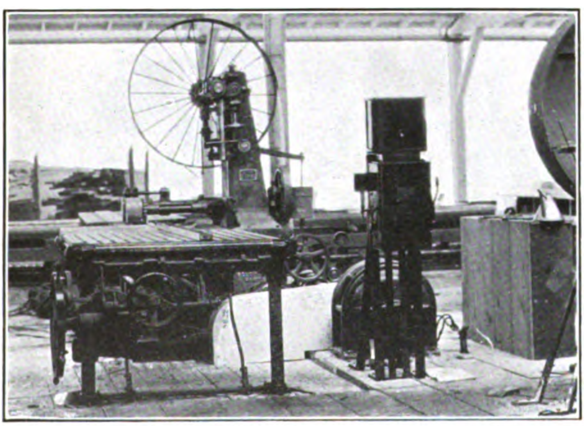
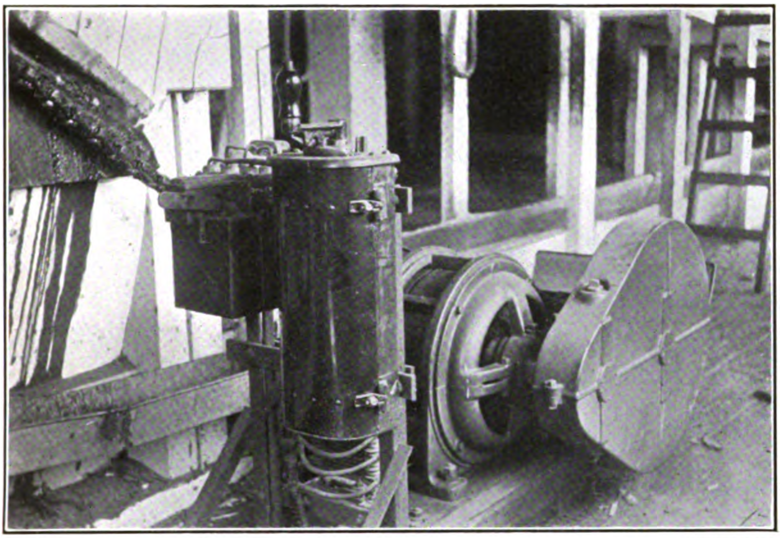


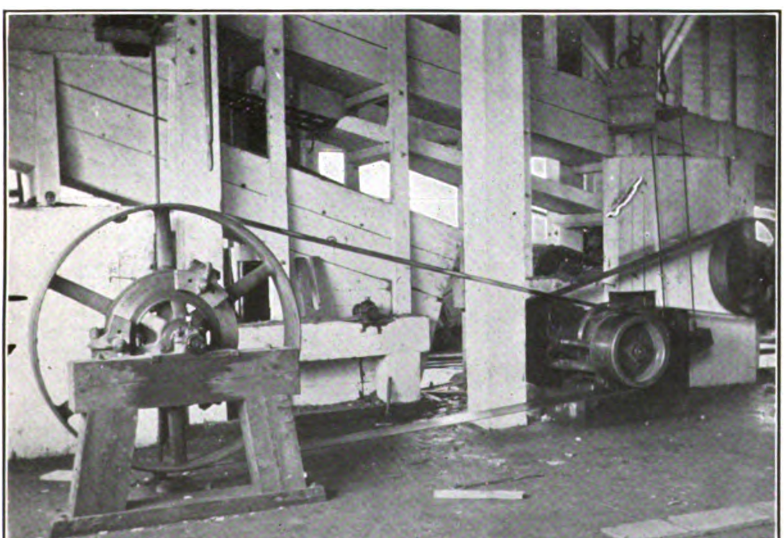
FIG. 29—BAND RIP SAW DIRECT-CONNECTED TO MOTOR. LARGE RE-SAW IN DISTANCE [WHITNEY]



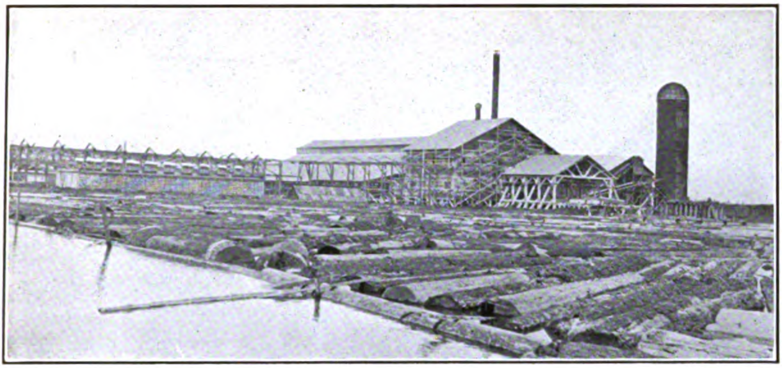
[WHITNEY]
FIG. 30—BAND RIP SAW DRIVEN BY SILENT CHAIN



[WHITNEY]
FIG. 33—BACK-GEARED MOTOR OPERATING CONVEYER

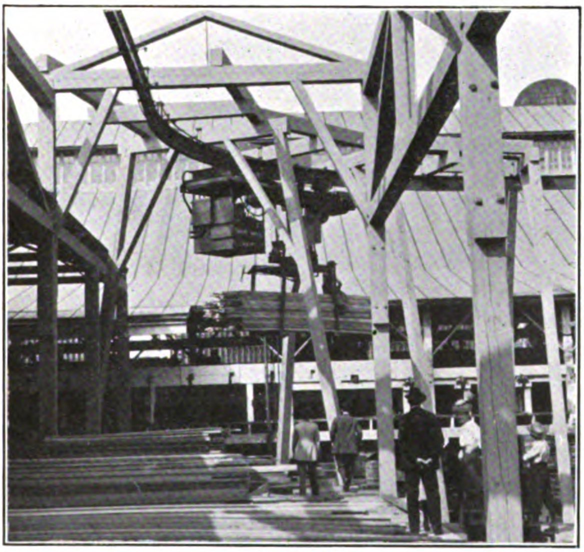


[WHITNEY]
FIG. 34—BACK-GEARED MOTOR BELTED TO BURNER CONVEYER



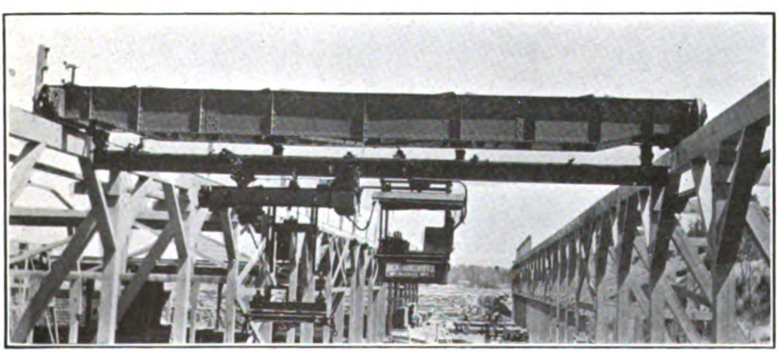
[WHITNEY]

FIG. 37—VIEW ACROSS LOG POND, SHOWING REFUSE BURNER



[WHITNEY]

FIG. 38—MONORAIL CAR WITH LOAD FOR DRY KILN



[WHITNEY]

FIG. 39—MONORAIL CAR AND TRANSFER CRANE FOR SPOTTING CAR AT DIFFERENT SECTIONS OF SORTING TABLE

FIG. 41—STORAGE BATTERY TRACTOR [WHITNEY]

[WHITNEY]
FIG. 42—FOUR-TON MONORAIL LUMBER-HANDLING CANTILEVER CRANE, 106 FT. TROLLEY TRAVEL, HAMMOND LUMBER COMPANY, ASTORIA, ORE.

[WHITNEY]
FIG. 44—MATCHER WITH 50-H.P. MAIN MOTOR AND 15-H.P. PROFILE ATTACHMENT MOTOR

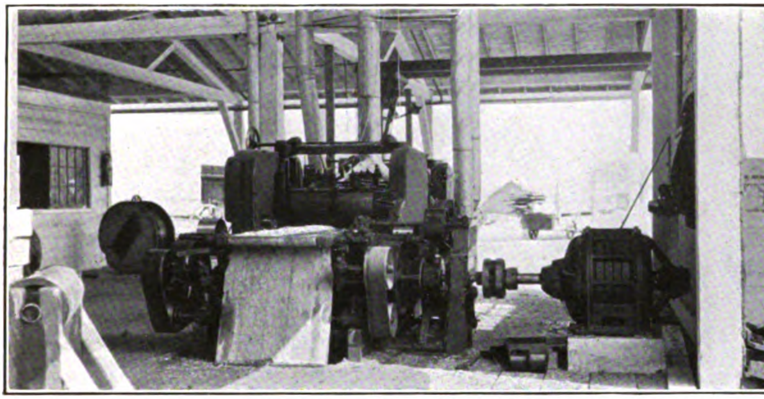
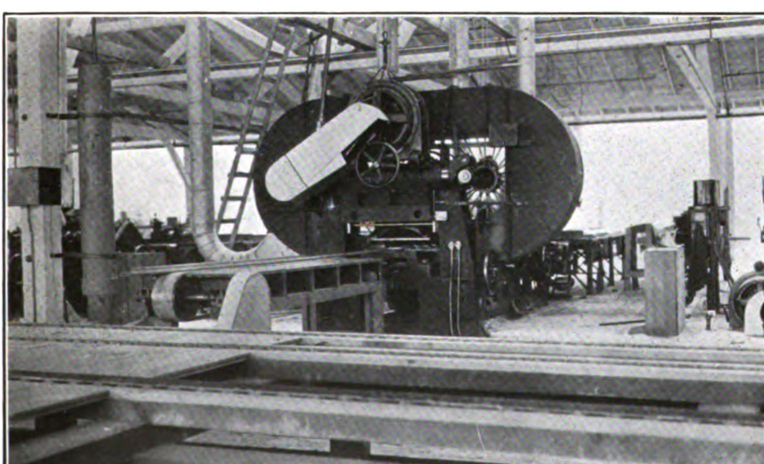


FIG. 45—TIMBER SIZER [WHITNEY]



[WHITNEY]

FIG. 46—RE-SAW END OF COMBINATION MATCHER AND RE-SAW, WITH MOTOR MOUNTED ON RE-SAW FRAME AND DRIVING BY SILENT CHAIN

away from the knives as fast as possible, so that some pneumatic suction system is necessary.

The edgings are first run through a gang of crosscut saws, a " slasher " with saws spaced 4 ft. (1.22 m.) apart. See Fig. 35. These slabs fall directly into the main mill wood conveyer, which has already received the stub ends from the trimmer which were less than 4 ft. (1.22 m.) long. From this conveyer, Fig. 36, is taken the stock for the lath mill and wood saws. The waste

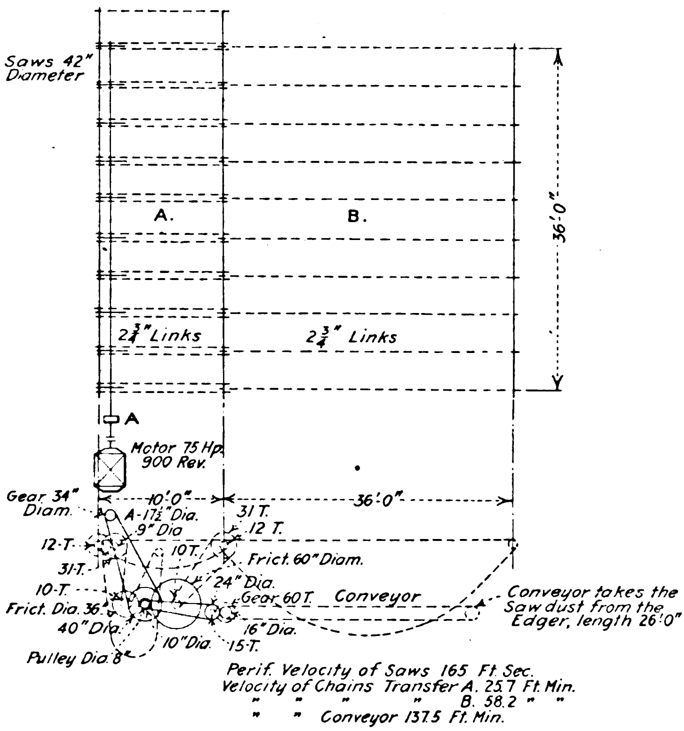


FIG. 35—SLASHER

which is suitable for neither of these purposes, continues to the " hog " and the refuse burner, Fig. 37. The " hog " hashes the refuse into small pieces suitable for use under the boilers, after which it is conveyed to the fuel storage bins. These appliances run at constant speed, and have fluctuating demands.

Dust from the machines is dumped into a main sawdust conveyer, which in turn delivers into the conveyer at the fuel bins. The shavings from the sizers are lifted by suction to a collector and from here blown directly to the fuel bin, Fig. 16.

Piping is usually large, because of the tendency of sawdust, if at all damp, to pack tightly at bends. Low pressures such as can be delivered by centrifugal fans are the rule. The pressure seldom exceeds 5 oz., but the volume is constant and consequently the blowing system is quite extravagant of power. The sawdust and hog fuel from the saw mill, planing mill, etc., if used for generating steam, is more than ample for the total power requirements of the mill. (See table of refuse fuel values at end of paper.)

Burners

Fig. 37 shows a typical burner in which the excess refuse and poor quality slabs are disposed of. These refuse consumers are a source of large expense to the mill operators. They must be substantially constructed; at the base, they are lined with fire

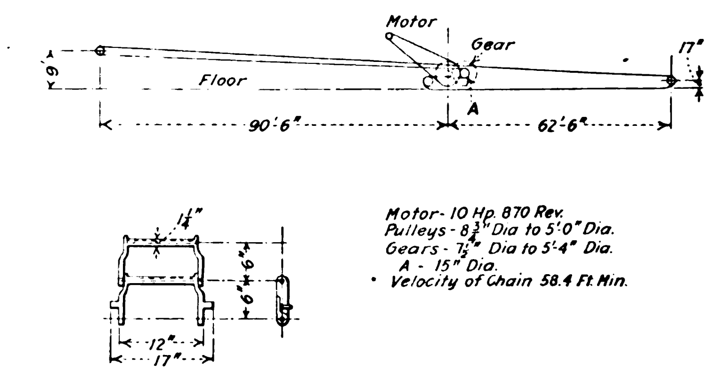


Fig. 36—Refuse Conveyer Drive

brick, and sometimes they are water-jacketed to quite a height. The first cost of a burner such as shown in the illustration is approximately $10,000. For a mill with a capacity of 150,000 ft. b. m. per day, the upkeep expense of such a burner would be approximately $1200 for interest and depreciation, and $1000 for maintenance. The life of an average burner is about 10 years.

Handling

From the sorting table the lumber is placed in bundles ready for handling. The most efficient method where location permits, appears to be by the well-known overhead monorail (Figs. 38, 39 and 40). The cost of handling by this method averages about $.10 to $.14 per M ft. b. m., which includes all expenses in connection with the system after the bundle is picked up until it is

placed in the storage yard or deposited at the dry kiln. This cost covers all charges against the system for labor and operating.

The first cost, installed, of such a system is $4.00 to $5.00 per lineal foot of track, including the hoists, and it provides about 2000 ft. b. m. storage space per foot of track. The monorail is usually operated by direct-current power at 250 volts, requiring a motor-generator set or small direct-current steam-operated set. The cost of handling with trucks and horses is approximately 25 cents per M ft. The horses are giving way, however, to storage tractors (Fig. 41), with the result that the above cost is reduced to approximately 10 cents per M ft. for average distances of handling.

For long hauls, storage battery or industrial type trolley locomotives are used. Traveling cranes of the bridge or gantry

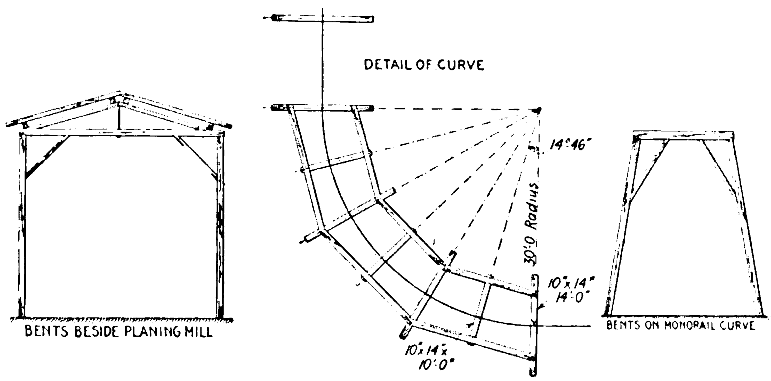


FIG. 40—MONORAIL STRUCTURE DETAIL

type are used by some of the larger mills. Fig. 42 shows a representative installation of this character. All of these installations have shown a very satisfactory saving in the expense of handling lumber.

PLANING MILL

As before mentioned, the material for this mill has usually been subjected to a drying process—either natural or artificial. All of the machines are designed for constant-speed drive, the variations in rate of speed being accomplished by changing the sizes of the feed roll driving pulleys. A general planing mill layout is shown in Fig. 43.

Power demands of planing machines have increased somewhat in the last few years, due to the development of fast-feed planers. This increase, however, has not been accompanied by a corres-

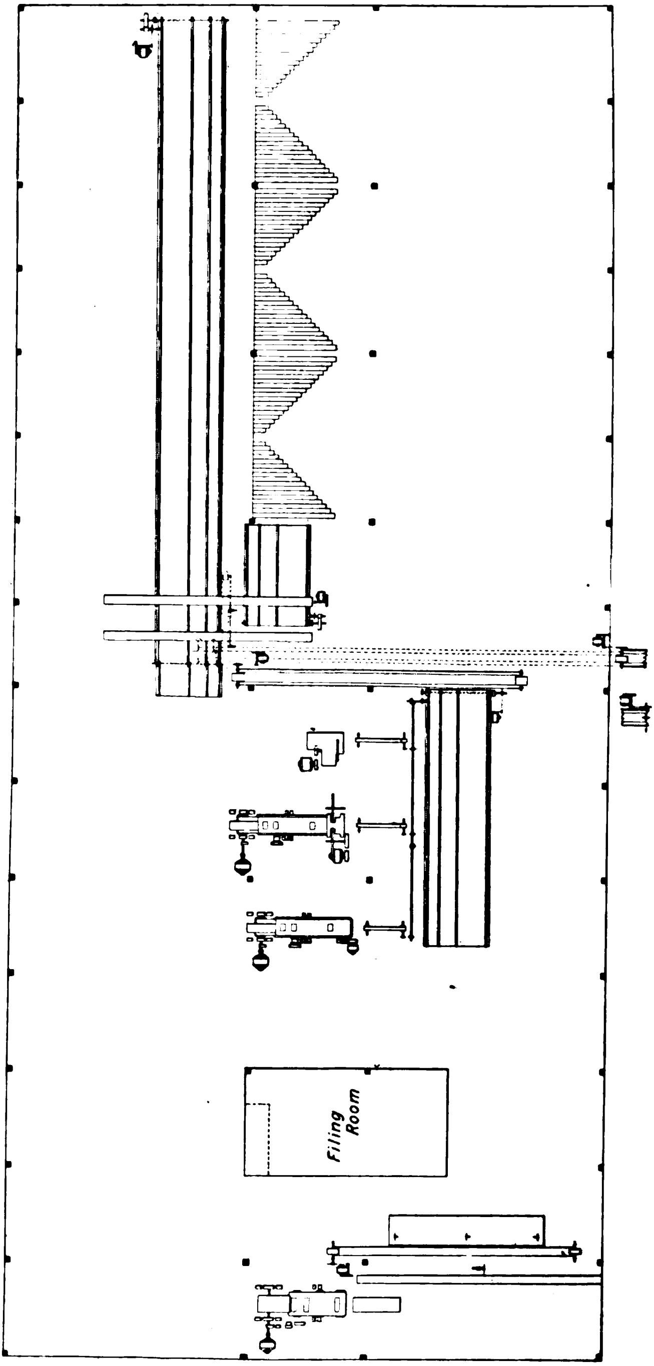


Fig. 43—Planing Mill Layout

ponding increase in motor sizes, as the present tendency is to utilize more fully the rated capacity under usual conditions, operating the motor at overloads when handling the heavier stock. It is universal practise to directly connect constant-speed, squirrel cage motors to the machine driving shaft, using a flexible coupling. Profile attachments are more conveniently operated by an individual motor driving the two profile cutting heads.

The starting duty of planers is rather severe, due to the large masses to be accelerated to high speeds. To this is traceable the common fault of "over-motoring" which was so much in evidence with the older, medium-feed machines. The advent of welded end-ring rotor construction has removed this obstacle.

The running load is fluctuating according to the small irregularities in the dimensions of rough stock. Friction load is approximately 55 to 60 per cent of the working load. The working factor of a planer seldom exceeds 60 per cent of its maximum capacity, since some time is lost in locating rough stock for the operator, and in changing from one size stock to a different size. Standard profile attachments run at constant speed and require 15 h. p. The starting duty is light and the running load fairly steady. Fig. 44 shows the main driving motor and profile attachment motor for a modern fast-feed matcher, and Fig. 45 a 60-h.p. motor driving a timber sizer in a planing mill which is called upon to perform a variety of operations, depending upon stock demands.

Combination Matcher and Re-Saw

On orders which will permit one side rough, the re-saw simply splits the stock after it has been properly surfaced. The power requirements of the matcher end do not vary from standard machines. The re-saw (diameter of wheel 54 in. or 1.37 m.—saw blade 7 in. or 18 cm.) requires 35 h. p. to drive it. The motor is mounted on top of the re-saw frame and its weight is supported by a counterweight from a sheave attached to the ceiling. The best method of drive for a re-saw so mounted is by a silent chain. The matcher end requires a 50-h. p. motor. (Fig. 46).

In isolated instances, fast-feed matchers have been fitted with individual motors for driving the various elements of the machine, *i.e.*—one motor driving the feed rolls and one for each cylinder or knife drum, etc. A modern fast-feed planer, size 6-in. by 15-in., feeding 200 to 250 ft. per min., requires motors as follows: top cylinder geared with cloth pinions to a 35-h. p. motor,

bottom cylinder to a 20-h. p. motor, side heads to 15-h. p. motors, feed rolls to 15-h. p. motor.

Such refinements have shown an actual saving in energy over the one-motor method, since all belt friction and slippage is eliminated. The high speeds required for the various parts of the machine, some of which do not fit standard speeds of a 60-cycle motor, made it necessary to resort to gearing with cloth pinions. Very satisfactory results have been obtained.

After being finished, the product from the planers is trimmed to remove defective portions; it is then sorted and bundled. Old practise required a trimmer table with a swing cut-off saw (Fig. 47) for each machine, the output being handled by hand after leaving the machine. Their work is very intermittent and the starting load is light. Squirrel cage, constant speed motors are used, the usual size being three h. p. Tests of a 20-in. saw follow:

Running light	1.2 kw. input
Cutting one 2 x 4 in.	3.8 " "
" two 2 x 4 "	4.8 " "
" three 2 x 4 "	7 " "
" one 2 x 6 "	5.1 " "
" one 2 x 12 "	6.2 " "
" one 1 x 6 "	2.7 " "
Approx. load factor	30 per cent
Demand factor	300 per cent.

The duration of a cut is very short, otherwise the size motor ordinarily employed would have to be materially increased.

The advent of fast-feed planers and matchers necessitates a greater capacity method of handling the output without entailing a too great labor addition. The scheme adopted is to group all planers so that their output falls upon a transfer table. At the end of this table is installed an automatic trimmer similar to but smaller than the saw mill trimmer. In this way one man can trim the entire output. A squirrel cage constant-speed motor furnishes a satisfactory drive, 25 h. p. being the average size motor adopted for this service.

The transfer tables and refuse conveyers in a planing mill are usually operated by back-geared wound-rotor motors with chain drive. The material to be handled is very light, requiring at maximum three to five h.p. motors for such service. (Fig. 48).

Besides the trimmings, the other refuse from the planing mill consists of dust from the saws and shavings from the planers. The sawdust and shavings are cared for by air suction and blower systems (see Fig. 16 for typical layout.) Usually

the trimmings are put through a small capacity hog and then handled by the same blower system, or conveyed to a wood bin for the local wood market.

Refuse Exhaust System

Ordinary centrifugal fans capable of giving 5 oz. pressure are commonly used. Motors are sometimes direct-connected to the fan impellers, but more often belted, since with the latter arrangement the speed of the fan can be changed from time to time to get the correct pressure required in the system. With direct-connected fans, the impellers are ordinarily pressed directly on the motor shaft extensions, the motor bearings caring for the slight additional weight of the fan impeller. Fig. 49 shows such an arrangement. Constant-speed motors are used for this service. The load is practically constant throughout the operation, and is slightly less when the planers are working than when idle, provided of course that the suction intakes are left open at all times. Double fans are ordinarily used, one side lifting the refuse and the other side blowing through the pipe line to the fuel bin.

It is common practise to install a simple low-pressure gate in the suction to each machine, so that that particular intake may be isolated when the machine is shut down, thus reducing the energy required.

The following is indicative of the average power requirements of fans under usual conditions, length of pipe line, intake openings, etc., being assumed normal:

Single	40-in. fans	20 h.p.
"	50 " "	25 "
"	60 " "	35 "
"	70 " "	50 "
Double	40 " "	35 "
"	50 " "	50 "
"	60 " "	75 "
"	70 " "	100 "

Another system which has proved economical in energy consumption makes use of a low-pressure centrifugal fan for suction only, and uses high pressure for blowing the dust through the pipe line to the fuel bin. With centrifugal fans used for both suction and blowing, all of the material handled is passed through the impeller itself, necessitating large clearances and a consequent loss in efficiency. With the high-pressure system, none of the dust or chips passes through the fan itself, but the discharge from the collector empties into a revolving drum with vertical

cylindrical compartments. The cylindrical cartridges thus formed are forced through the pipe line as each compartment revolves under the compressor discharge. Centrifugal compressors and positive pressure blowers find a wide field in the high-pressure system.

Shingle Mills

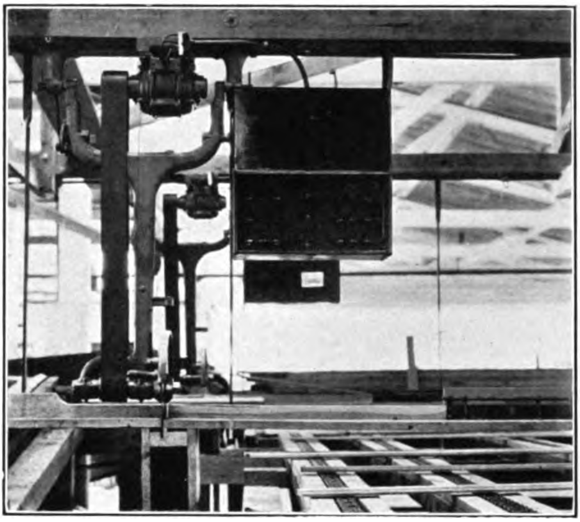
Figs. 50 and 51 show the latest tendency in the layout of shingle mills. The logs are handled in the same way as in a saw mill, after which they are cut into bolts, which go to the shingle machines and are finally trimmed, sorted, bundled and dried. Fig. 51 gives the main floor plan of an electrically driven mill, while Fig. 50 shows the elevation of a later mill. The latter was originally planned for steam drive, but later changed to electric, so that the elevation shows a line shaft in error. In the final plans, this was eliminated and the driving motors connected to the shingle machines, as in Fig. 51. Fig. 52 shows the shingle machine floor of this mill, which is the first, of which we have record, using individual motor drive throughout. Its operation has been very satisfactory. Of all the machines used in these operations, only the shingle machines, shown in Fig. 52, differ from those already described for other operations.

The standard upright shingle machine requires two motors for its best operation—a 20-h.p. motor driving the main saw and mechanism and a 3-h.p. motor driving the trimmer saw—both constant-speed, squirrel cage motors direct-connected to the driving shafts. The power requirements of the complete machine—both the shingle saw and the trim saw—are about 18 kw. input, no-load, and 20 to 21 kw. input when cutting.

General

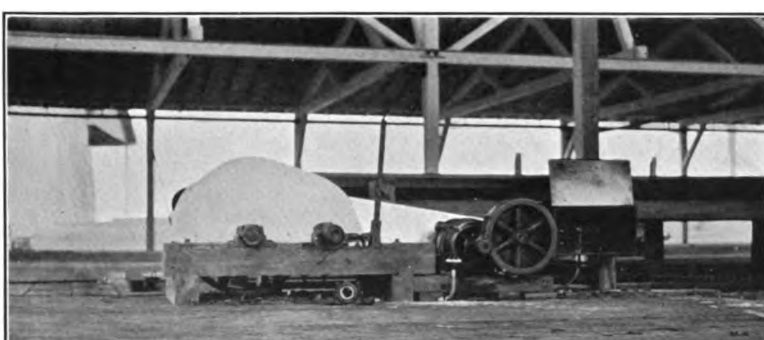
In general it is estimated, in a mill using steam engines with line shaft drive, that 8 to 10 h.p. per M feet b.m. capacity per 10-hour day, is required for the sawmill machinery only. This old rule-of-thumb method was close enough for practical purposes, since with maintained steam pressure the engines had large overload capacities, but with very poor speed regulation. This poor speed regulation is noticeable in most all steam-driven mills. The friction load is enormous, requiring often 40 per cent of the rated engine power when running the mill idle.

With the advent of electric drive, the motor horse power installed will approximate 11 to 13 h.p. per M feet b.m. capacity per day, for both sawmill and planing mill.



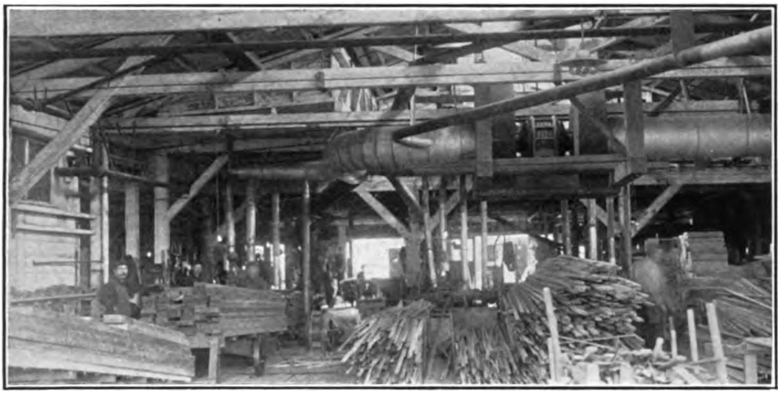
[WHITNEY]

Fig. 47—Swing Cut-off Saws for Trimming Planing Mill Stock



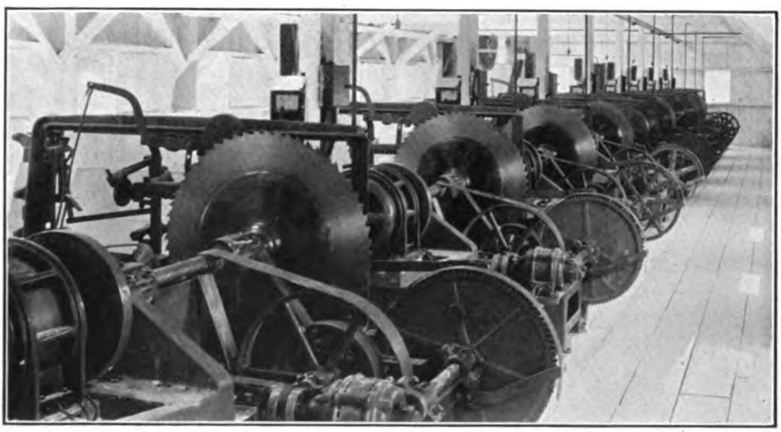
[WHITNEY]

Fig. 48—Sorting Table Drive in Planing Mill, with Back-Geared Motor



[WHITNEY]

FIG. 49—DOUBLE 60-IN. EXHAUST FAN DIRECT-CONNECTED TO MOTOR



[WHITNEY]

FIG. 52—INTERIOR OF SHINGLE MILL USING ELECTRIC DRIVE. THE COMPACT MACHINES AND ABSENCE OF TRANSMISSION BELTING IS IN MARKED CONTRAST TO THE CROWDED APPEARANCE OF BELT-DRIVEN MILLS

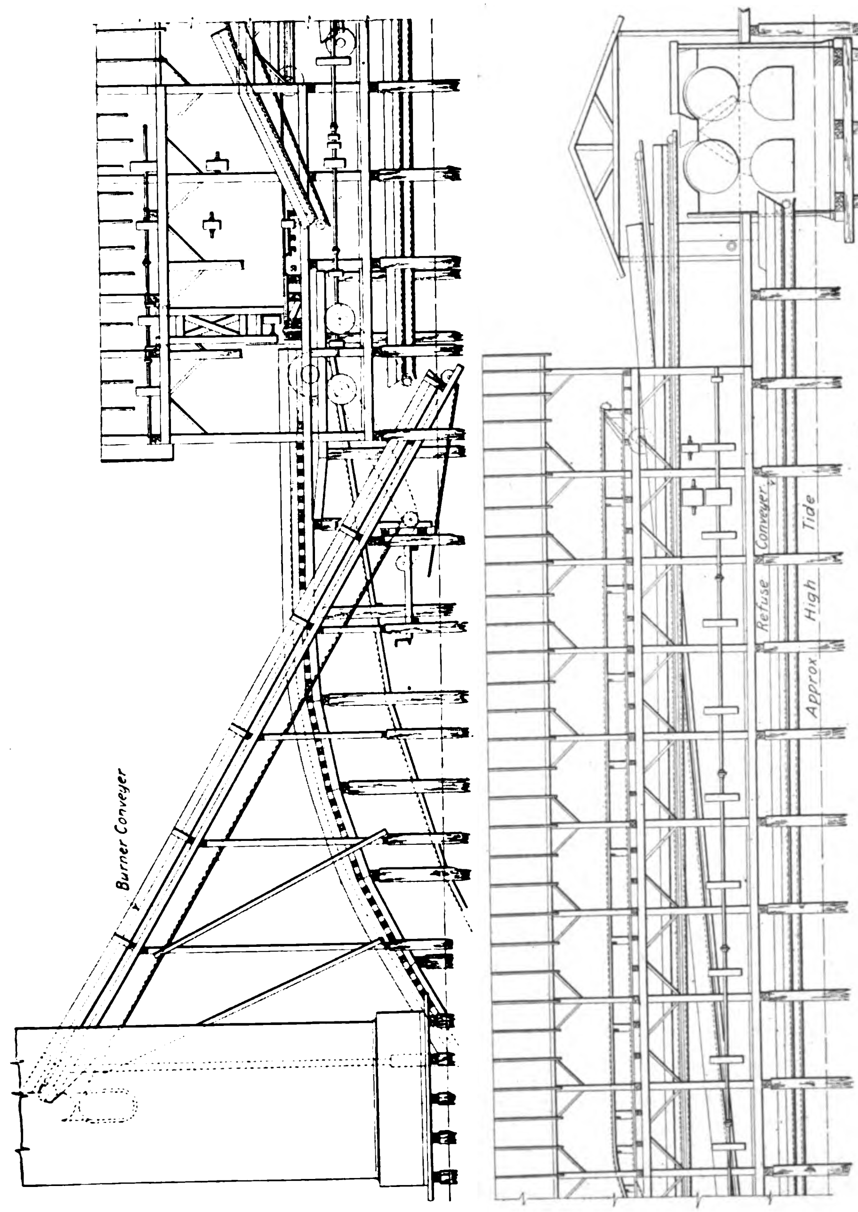


FIG. 50—ELEVATION OF SHINGLE MILL

The energy required for manufacturing 1000 ft. b. m., including planing mill operation, has been found to vary from about 29 kw-hr. in the white pine district to 46 kw-hr. in the fir dis-

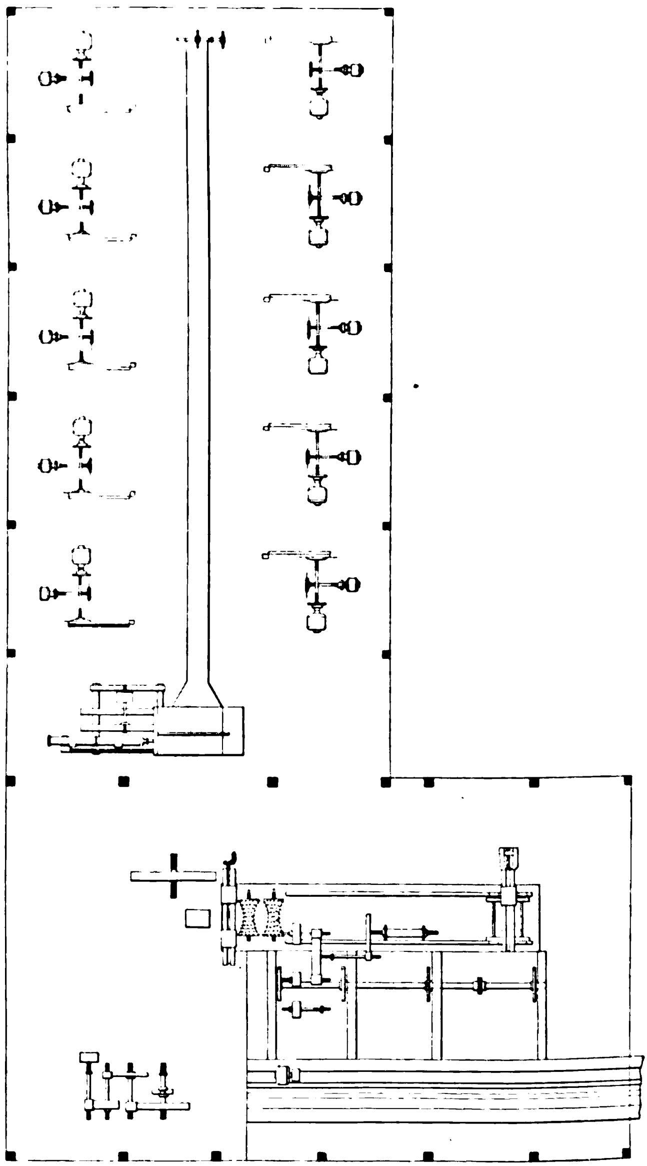


FIG. 51—SHINGLE MILL PLAN

trict of the Pacific Coast, which would indicate an actual electrical horse power of from 3.8 to approximately 6 h.p. per M feet daily capacity of an electrically operated mill.

The cost of power to the average saw mill operator means very little, due to the large wastes which they must experience in their manufacturing operations. Those mills, located remote from any available market, must dispose of this waste either by generating power for their own use or consuming it in refuse burners.

Refuse—Uses and Fuel Value

The question of refuse disposition is one of the large items of expense in connection with the average mill. A solid log scaling 1000 ft. b.m. will, when cut, give about 1150 ft. b.m of lumber, and the refuse in the form of sawdust, trimmings and edgings will amount to a little more than a half cord, or the equivalent of 115 cu. ft. of cut fuel. Adding the refuse from the planing mill and other manufacturing departments, the total loss may easily reach 40 per cent of the original scale of the log. Of course the greater refinements in using the by-product will reduce the proportionate amount of refuse.

Except for fuel, the uses for this have been very narrow. Attempts have been made to use sawdust from Pacific Coast mills, which cut mostly fir, spruce and hemlock, for manufacturing wood alcohol and ethyl alcohol. In practise, however, the manufacturing costs run so high that it has proved unprofitable. The latest projected use is in making sawdust briquets to be used for paving purposes, and also for use as fuel. Such a plant has been completed, although its operations have not extended over a sufficient period to determine the ultimate success.

As fuel, the refuse values, wherever there is an available market, are shown by the following data:

Wt. one cu. ft. wet sawdust	21 lb.
Per cent moisture	48 to 52 per cent.
Heat value per lb. wet sawdust	3500 B. t. u.

Wet sawdust means that in its natural state coming directly from the mill operations, and includes cut fuel from the hog. The dust from planing mill operation is relatively dry, and as fuel, has a value per pound of 8500 B.t.u. These values are averages of a number of analyses and apply to sawdust from mills cutting mostly fir and spruce. As ordinarily found in the fuel bin, the mixture has some intermediate heating value. Sawdust is usually sold in units of 200 cu. ft., the equivalent of about 0.88 cord of slabwood.

Slabwood is cut to 4-ft. lengths and sold by the cord. It also has a wide use as fuel, though as such it is more expensive than sawdust.

The following table gives the average values of wood fuel as compared with oil and coal, the costs of the various fuels per unit being assumed as in column five. Column two gives evaporation values taken from tests at the same plants, using the fuels named.

	B. t. u. per lb. dry fuel	Lb. water evaporated from and at 212 deg. per unit.	Cost per 1000 lb. water from and at 212 deg.	Cost per unit of fuel
Sawdust	8,500	(200 cu. ft.) 10,500	9.5 cents	$1.00, 200 cu. ft.
Slabwood		(1 cord) 12,500	24 cents	3.00, 1 cord
Split cord wood		(1 cord) 13,500	37 cents	5.00, 1 cord
Oil	18,500	(1 lb.) 15	21.9 cents	1.10 per bbl.
Coal	11,000	(1 lb.) 7.2	41.6 cents	6.00 per ton

To be presented at the 302d Meeting of the American Institute of Electrical Engineers, New York, December 11, 1914.

(*Subject to final revision for the Transactions.*)

INSULATOR DEPRECIATION AND EFFECT ON OPERATION

BY A. O. AUSTIN

ABSTRACT OF PAPER

Investigation shows that insulator trouble increasing with time is not due to fatigue in the material under applied working loads, but rather to depreciation caused by the absorption of water by porous material or by the cracking of the dielectric from high internal mechanical stress set up by uneven temperature in the dielectric, or by greater expansion of cement or metal, or stress from a combination of these.

The shape of the dielectric may cause high maximum stresses under comparatively mild conditions, necessitating the working of material with a lower factor of safety than that permissible even in steel work. The high maximum internal stress under which insulators operate will cause considerable depreciation in some types through cracking, necessitating a careful study of the effect of depreciation upon the operation of the system. Trouble comes largely through the matching up of faulty parts so that the remainder of the insulator will be destroyed by a comparatively mild surge. Applying the theory of probability, it is then possible to obtain a relative operating hazard for the insulator under the same conditions or for varying degrees of depreciation.

An equation for the operating hazard may be developed which gives a good idea of the relative economic importance of the number of sections in the insulator, the magnitude of the switching surge and the rate of depreciation as affecting the reliability of the system.

The study of depreciation shows that routine tests which will tend to eliminate future depreciation, or refinements in the mechanical features of the insulator, are of far more importance in producing reliability than the designing of insulators to withstand extremely severe dielectric design tests, for insulators which may have extremely high dielectric strength will cause trouble through cracking from internal stress.

THE growing investments dependent upon the transmission line make the study of factors governing reliability in the insulator of ever increasing economic importance. In view of this, it is hoped that this article will throw some light on insulator failures and be of assistance in deciding on the refinements and size of insulator necessary for a given system.

Even with more severe conditions placed on the insulator, recent lines have continued to make a much better showing. Some systems have had no insulator failures while others have

operated for a period of several years only to run into increasing trouble, in some instances necessitating the entire reinsulating of the line.

Where insulator trouble increases with time, it is only natural to attribute the trouble to fatigue in the insulator. Upon looking into the subject, however, it is evident that this is not necessarily the case, for the failures may be due to a number of entirely different causes.

Suspension insulators give the best available data, although failures of pin type insulators have been far more numerous, in some instances a visual inspection showing cracks developed in over 60 per cent of the insulators.

A few pin type insulators which have cracked after several years' service are shown in Fig. 1. An examination of this class of failure shows that there must be a strong radial force which splits the outer parts or shears the head of the cylinder from the side wall. This force can come from several sources, but as the porcelain does not seem to be appreciably affected either mechanically or electrically outside of the cracks it would appear that the breakdown is due more to a rather high stress, than to a low stress acting for a long time.

It is quite likely that the stress set up is that due to uneven expansion from varying temperature and from an expansion of the cement.

Porcelain, like most dielectrics, is a very poor conductor of heat, so if the insulator has become hot in the sun or from surface leakage, and is then suddenly cooled by rain there will be a considerable difference in temperature between the outer and inner parts. This difference in temperature may set up an average tensile stress of several hundred pounds in the outer members.

This average stress is hardly high enough to cause any damage but the shape of the dielectric may be such that a very high maximum stress is set up, causing a crack, as along AB in Fig. 2.

There is no doubt that the defect comes from internal stress, but as this stress may be set up by uneven temperature and expansion in the dielectric or by cement expansion, it is not easy to determine the cause.

Tests on the insulators show that there may be considerable difference in temperature between inner and outer surfaces which may account for destructive stresses in some instances, but hardly accounts for failures in other cases, particularly where insulators have been known to crack in storerooms and in protected places where there has been no sudden change of temperature.

It is also significant that trouble usually develops at railway crossings first. While it is possible that the insulators may become hotter, owing to the black surface or increased leakage, it appears that the sulphur fumes in the smoke attack the cement and increase the crystalline growth presumably of calcium sulphate. This crystallization causes expansion, setting up a stress which, combined with that due to difference in temperature, may produce exceedingly high strains.

It is not surprising that there should be some trouble from cement expansion, for in general, little attention has been given

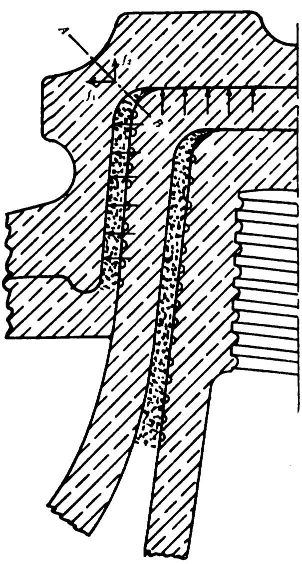


Fig. 2

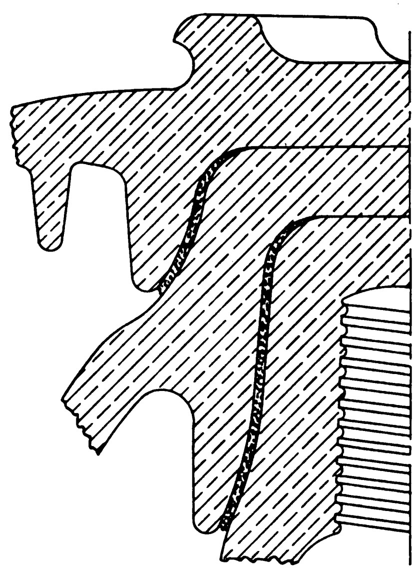


Fig. 3

to this rather difficult subject, and even where there has been, it is difficult to predict expansion from the formation of acids by static discharge in the cement or effect of continued weathering.

Owing to deficiency in mechanical strength, European porcelain does not seem to withstand the mechanical stress very satisfactorily, and it has been general practise abroad to avoid cementing, or to use special cements at greatly increased cost.

A microscopic examination of the cement sometimes shows a marked crystalline growth in the cement, particularly where the insulators are near railroad crossings, or in cement exposed to continued weathering.

Fig. 4 is reproduced from a photomicrograph of cement taken from the insulator on the right of Fig. 1. Taken at a magnification of 49 diameters a few crystal growths are visible. Fig. 5 shows a marked growth in the cement from a strain insulator. These insulators gave trouble in a little over a year, so it is evident that cement expansion played an important part in causing failure.

Fig. 2 shows a section of an ordinary pin-type insulator which usually cracks along the line AB. It is readily seen that a contraction of the outer part or expansion from the cement will set up a very high stress along AB. As this stress is highly concentrated in most insulators, owing to two components at nearly right angles, the break often occurs through a very thick part.

The large cement spaces and shape of the insulator greatly increases the hazard or danger of cracking in the insulator shown in Fig. 2. In Fig. 3 is shown one of the later designs of insulators which have proved to be practically proof against lightning and it is evident that the stress set up by uneven heating or cement will not only be less, but the strength of the parts resisting these stresses will be greater.

This type of insulator has low working stresses, so it is possible that high-frequency disturbances which would cause a considerable heating of the cement in the insulator shown in Fig. 2 would have little or no effect on the insulator shown in Fig. 3. Also refinements in cement, or the elimination of a portion of the stress by dipping the ends of the shells in an elastic varnish or wax or the insertion of a cushion which would be beneficial in Fig. 2, would be entirely unnecessary in Fig. 3.

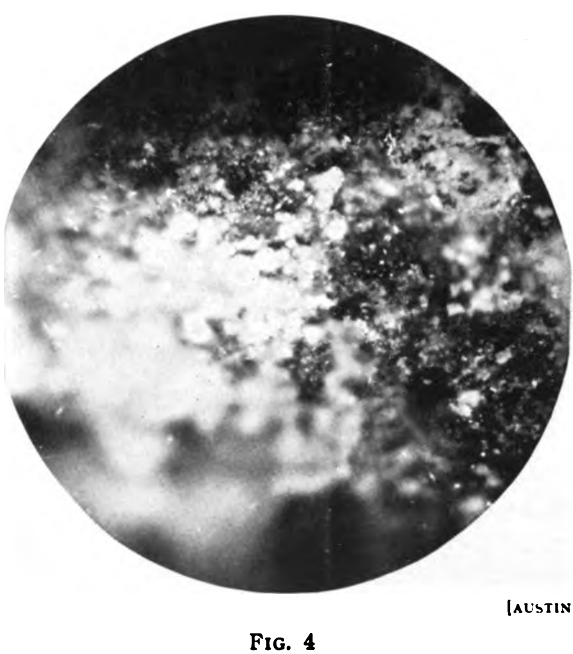
The material is so distributed in the later types of insulators that not only are exceedingly high tests obtained on the parts, but a small protecting air path is provided between conductor and pin to act as a safety valve for surges.

Fig. 6 shows an improved insulator, a section of which is shown in Fig. 3, flashing over at 216 kv. for a striking distance of 14 in. (35.5 cm.), and having a total part test of over 300 kv.

There is nothing in practise to show that anything would be gained by increasing the conductivity of the cement in insulators of this type or metallising the surfaces to reduce heating from flow of charging current under high-frequency surges although tests on the oscillatory transformer may show that this is beneficial in the ordinary insulator with its high charging current.

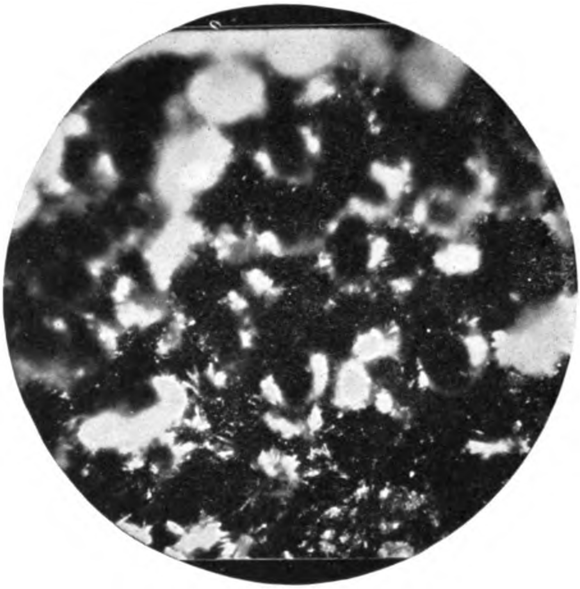
[AUSTIN]

FIG. 1



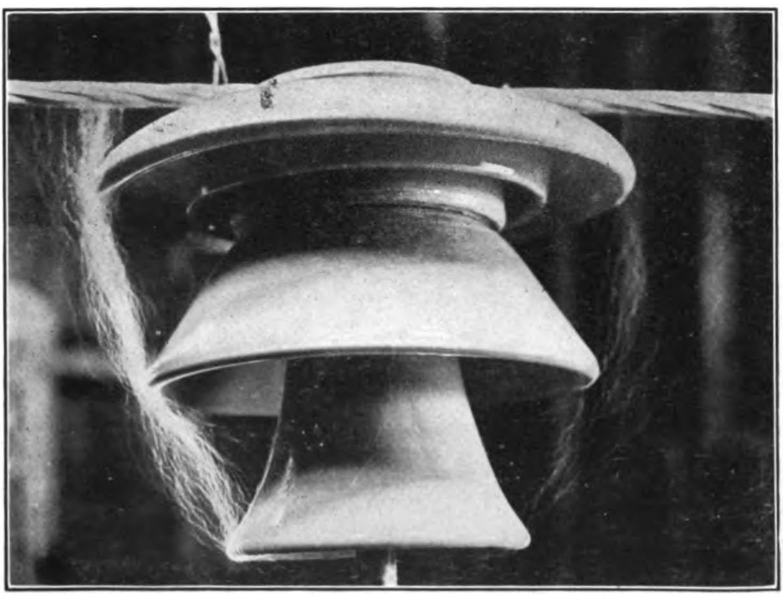
[AUSTIN

FIG. 4



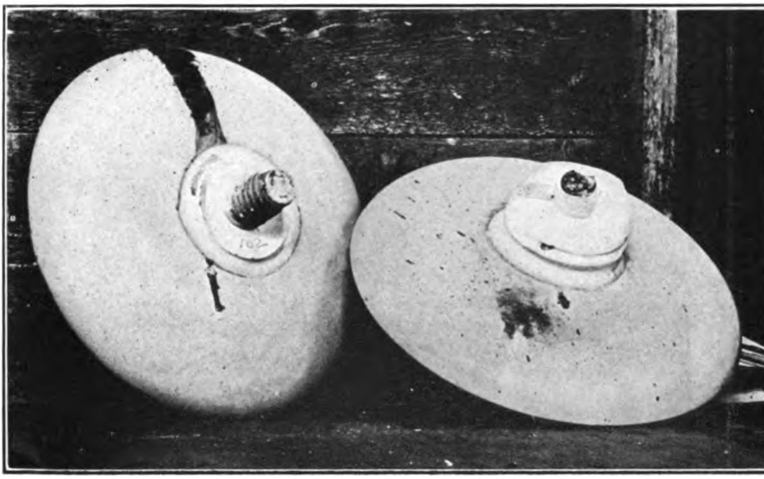
[AUSTIN]

Fig. 5



[AUSTIN]

Fig. 6



[AUSTIN]

FIG. 7

[AUSTIN]

FIG. 8

Fig. 7 shows typical breaks in two different suspension insulators. On the left is shown a disk with crack in the groove at the shoulder from combined expansion of the cap and cement exposed to weathering. The stress is concentrated by the shape of the insulator and the cement groove. This groove affects the strength somewhat like a scratch in a pane of glass. Insulators may also be cracked slightly at this point by too high mechanical tests or rough handling, although there is no outward sign. The elimination of the cement next to the flange and the substitution of a sanded surface in place of the grooves for holding the cement greatly reduces the maximum stress.

To the right of Fig. 7 is shown a failure in an insulator of similar design but of different material. These insulators have transverse cracks in the bottom of the grooves, showing that the insulators would not withstand the elongation of the metal under the highest working temperature. A higher assembly temperature would improve this or preferably a sanded surface in place of grooves, for the latter would be free from the objection of high shearing stresses in cold weather.

A magnified view of a sanded surface is shown in Fig. 8. In addition to eliminating grooves which tend to concentrate both electrical and mechanical stress, this surface is of equal gripping efficiency in any direction. This latter property greatly reduces the maximum stress set up in insulators working under heavy mechanical loads.

As there are records of insulators working under loads which set up stresses of at least 50 per cent of the ultimate, it seems quite probable that most mechanical failures are due to stresses very much higher than have been thought possible.

It is possible that vibratory stresses which are most severe in dead-end insulators may cause a breakdown of the dielectric structure which, with the greater weathering, may account for the very much poorer showing made by dead-end insulators in some cases.

It is certain that, where the maximum stress is very high and fluctuating with temperature, it will be only a matter of time before the molecular structure of the dielectric will be destroyed. Where this is combined with an increasing stress from cement expansion it is apparent that failures may be very serious in time, although there is little evidence of this during the early years of operation.

While only defects from mechanical stresses have been con-

sidered, there are others of an electrical nature that are always present and in many instances are far more serious.

Good porcelain will withstand considerable heat, so material which acts as a resistor may pass electrical tests successfully, only to depreciate very rapidly in service owing to the absorption of water, which greatly lowers the resistance.

Porous material or that which lacks vitrification, while withstanding high voltages at time of installation, gradually loses its ability to carry electrical stress. Where the absorption is slight the insulator may have an appreciable amount of dielectric strength after a number of years, but where the absorption is large there will be little insulation in a year or so. On some of the earlier lines there was a large percentage of porous ware, which accounts for the poor operation until this material was weeded out.

An investigation of one of the large systems showed that out of 2 per cent of insulators shown to be weak by the megger, at least 1.4 per cent were poor owing to lack of vitrification, and could be detected by the trained eye.

Of the remainder, part were defective owing to porous streaks or the developing of faults left by the burning out of lint or other impurities. This really made the percentage of insulators which were poor, owing to conduction, over 1.4 per cent. It was not possible to classify some of the rema'nder outside of those having failed by cracking.

Fig. 9 shows a small fault detected by the megger and later burned by a very small current.

Porous insulators, while forming by far the largest percentage of defective members in the better designed insulators, can be detected to a large extent by Mr. Gaby's megger method and removed from the line.

For the factory use, it is advisable to use a more sensitive instrument than the megger in order to detect insulators which have very minute defects or are only very slightly deficient in insulation.

Fig. 10 shows a galvanometer which may be worked on a very high direct voltage obtained by rectifying and charging from the peak of the wave. Surface leakage has given considerable trouble, but it is hoped that improved means for shunting this surface leakage current will make this method very valuable.

Failures from electrical stress may be gradual, for it is possible to puncture porcelain several times, where the flow of current is

extremely small, before complete failure occurs. For this reason surges sometimes do considerable damage to a system and their effect is not noticeable until the cumulative damage causes a complete breakdown.

Since the static breakdown is in the nature of a very slight mechanical fault, it is not surprising that a comparatively low electrical or a mechanical stress will cause complete breakdown in time.

The success of some of the later types of insulators, however, shows that there is little to be feared from static puncture as compared to some of the other defects in the insulator.

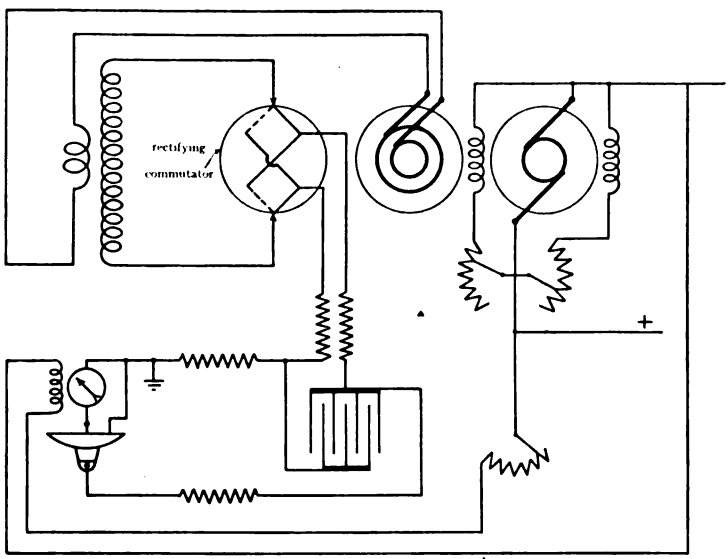


FIG. 10

In well-insulated lines, trouble comes not by the depreciation of the insulators as a whole, but by the matching up of defective parts in a single insulator or string such that the normal voltage or a switching surge causes the insulator to spill over or puncture. Just what the factors governing this are, was not apparent until some recent investigations caused this matter to be investigated and more thoroughly analyzed.

The investigation of some of the systems shows that there is practically no successive breakdown in the insulator, and that faulty members are about equally distributed throughout the string. This, with the total absence of punctures during several years' operation on lines like the Shawinigan Water and Power

Company, Fig. 11, and the 140-kv. Au Sable Electric Company's line, Fig. 12, shows that there is little danger of puncture from high-frequency surges where the insulator is made up of six or more closely spaced, well tested sections.

Lines of this class have also shown that the modern line is practically lightning-proof, for these systems have not averaged one kickout in two years from the spilling of insulators, from lightning or any other cause. This performance has, of course, been much better than was thought possible when the lines were insulated, and shows that spill-overs which have caused so much trouble on some lines can be prevented on a new system at a comparatively low cost for insulation.

The big problem in line insulation is not so much to design for high-frequency but first of all to prevent depreciation as far as possible, or at least to minimize the danger due to matching up of faulty parts in the insulator, for it is evident that if an insulator has a large number of parts which become bad through absorption or cracking, trouble is sure to follow regardless of the fine showing of an insulator on high-frequency tests.

Since the line trouble on the better insulated lines will come from the matching up of parts in the insulators which have become bad with time, rather than from lack of dielectric strength provided by the design, it is necessary that we recognize these conditions in order that the good operation of the system be maintained or established economically. To this end it is well to consider the probability of trouble from this source and analyze the problem, in order that the relative importance of the factors governing the matching up of the faulty parts to the danger point may be obtained.

Let p = per cent depreciation, or average number of parts bad in 100.

n = number of parts or disks in the insulator or string,

b = number of parts which may be bad in a single string when danger point is reached,

$g = (n - b)$ = number of good parts in insulator when danger point is reached,

P = probability of a string being dangerous,

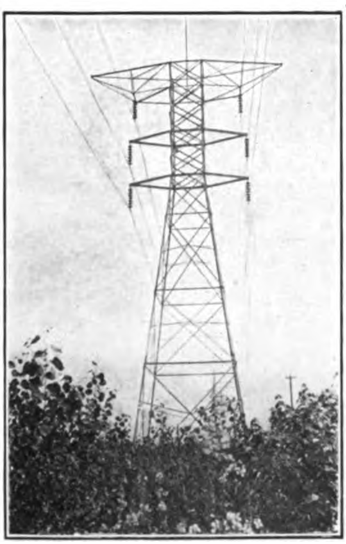
N = number of strings on the system.

From the theory of probabilities it follows that the probability of all the parts in a given insulator being faulty will then be

$$P = \left(\frac{p}{100}\right)^n \qquad (1)$$

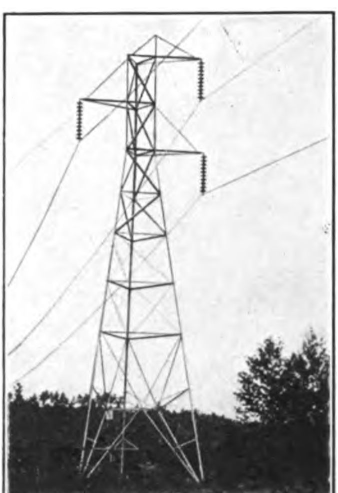
[AUSTIN]

FIG. 9



[AUSTIN]

FIG. 11



[AUSTIN]

FIG. 12

Switching surges, however, will usually spill or puncture several parts, so it is necessary to assume a dangerous condition when only a portion of the insulator is bad. Equation (**1**) is then important only when the line is insulated with a single part or has not carried voltage.

Where the danger point is reached when there are b parts bad, the probability of a string being dangerous becomes

$$P = \left\{ \left(\frac{p}{100}\right) \left(1 + \frac{g}{b}\right) \right\}^b \tag{2}$$

The above follows from equation (**1**), for as we are concerned with the matching up of b units only, n becomes b in the permutation, and as all the units contribute to make up the faulty b members the percentage depreciation must be increased by $\frac{g}{b}$.

Substituting $(n - b)$ for g in (**2**) gives

$$P = \left\{ \left(\frac{p}{100}\right) \left(1 + \frac{n-b}{b}\right) \right\}^b \tag{3}$$

$$= \left(\frac{p\,n}{100\,b}\right)^b \tag{4}$$

In order to obtain the number of dangerous strings or insulators on the system, it is then necessary to multiply P by the total number of strings on the system, or

$$NP = N \left(\frac{p\,n}{100\,b}\right)^b \tag{5}$$

gives the probable number of dangerous strings on the system.

In Fig. 13 are shown some curves where the minimum insulation is maintained for various number of parts n in the insulator. These curves show that a line having only 2 per cent depreciation and a switching surge that would spill two parts would have 30 dangerous strings in 1000 strings, where there were only three sections in the insulator. The addition of another part, however, reduces this hazard about 95 per cent and the addition of still another part reduces the probable dangerous strings to 0.064 in 1000 strings.

These curves show the economic importance of having a sufficient number of parts in the insulator in order to produce reliability.

Operation bears out these curves, for systems which were under-insulated have been very greatly improved by slightly increasing the insulation.

In Figs. 14 and 15 is shown the effect of varying depreciation

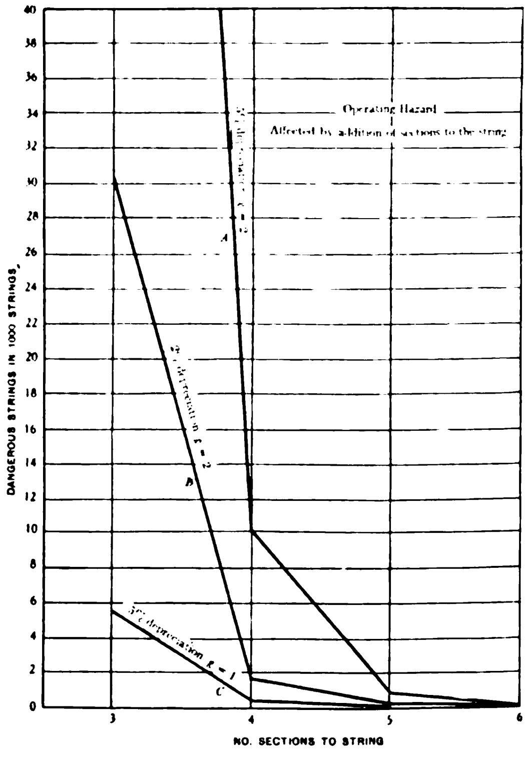


FIG. 13

for different insulators where the number of parts and minimum possible insulation is constant.

These curves show that the operating hazard increases very rapidly with the increase in the rate of depreciation, particularly for insulators which have only a small margin above the switching surge. It is also apparent that the reduction in the magnitude of the switching surge which allows an increase in b for a given insulator will greatly improve the operation of a system.

This point should not be overlooked for it is of considerable economic importance, as resistance or reactance in the switch costs but little compared to an increase in the total insulation of the system. The curves also show that the advantage gained by building up the voltage and the elimination of the switching surge should not be underestimated, particularly where the system is having trouble.

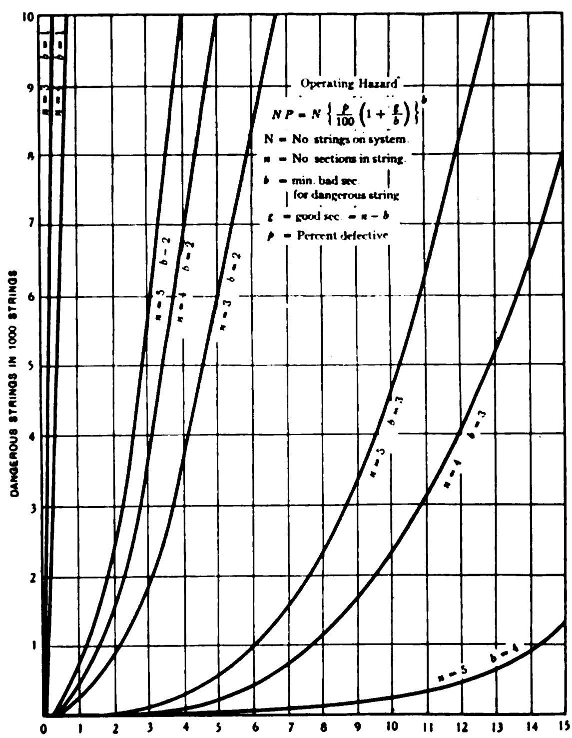


FIG. 14

Space will hardly permit at this time of a thorough discussion of the relative economic importance of the effect of depreciation, number of sections, or the magnitude of switching surge on the reliability of the system, but the curves will give a very good idea of the vast importance of the matching up of defective insulators in producing line trouble.

Where the depreciation is due to porous material, "meggering" of the line will weed out this material and the operation will be

greatly improved. If, however, the internal stress in the insulator is high, causing the insulator to fail at an increasing rate through cracking after several years' operation, it is evident that it may become very difficult to maintain the best of operation unless the line is gone over quite frequently. Trouble from the latter will be lessened by distributing new insulation uniformly throughout the different insulator strings.

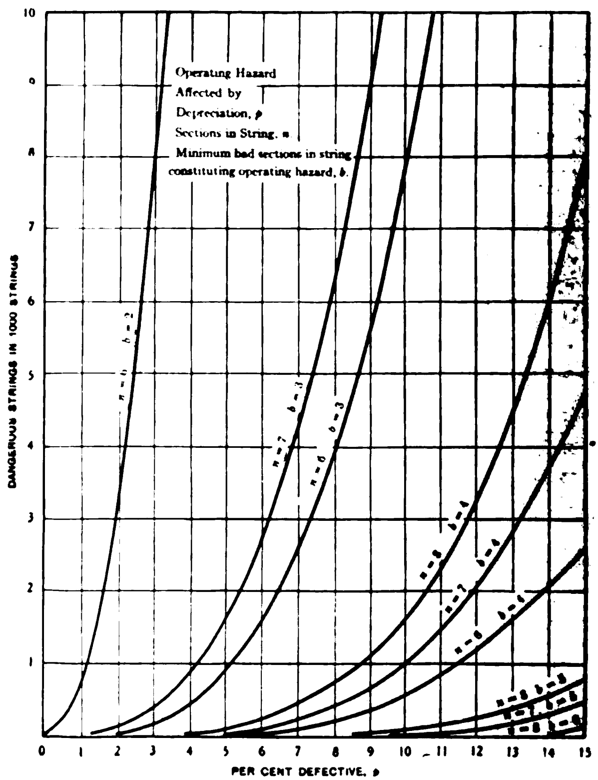
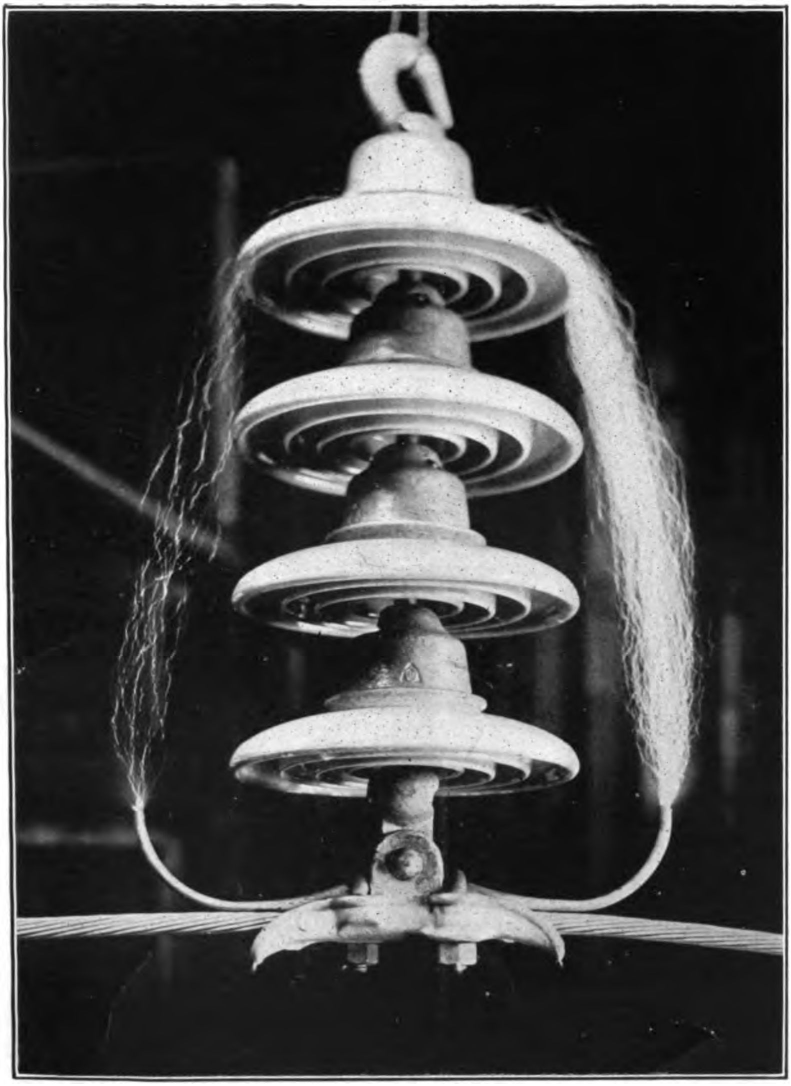


Fig. 15

Since the trouble on the line comes not from the insulator of average strength but from the insulator having the large number of weak members, it is highly important that the characteristics of the weak insulators be given careful consideration.

It must be remembered that even though the insulator is subjected to a flash-over voltage, the probability of failure decreases with the increase in the number of sections in a closely spaced insulator and that a large insulator may operate under very severe



[AUSTIN]

FIG. 16

conditions while an insulator composed of a few sections may fail, owing to lack of sufficient factor of safety, although the flashing voltage was much lower.

Since we have plenty of evidence to indicate that there is little to be feared in the large insulator, it is apparent that where failures occur it is usually due to the lack of factor of safety in the remaining good insulators in a string.

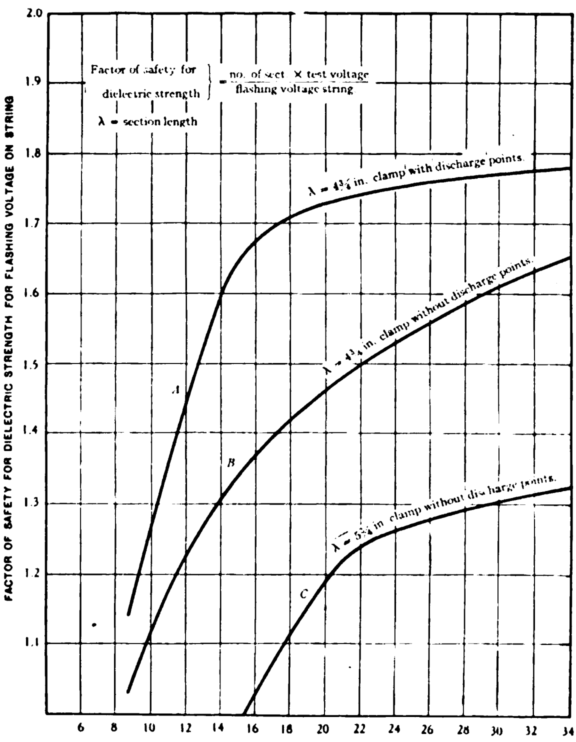


FIG. 17

The use of discharge horns and very closely spaced insulators improves the factor of safety for an insulator having only a few units. The insulator of this type is shown in Fig. 16. Fig. 17 shows curves based on this insulator and it is apparent that while the discharge points on the clamp greatly improve the factor of safety for a few units they do not materially improve the factor of safety for a long string. Since, however, depreciation is likely to reduce the total number of good units in a string, it is advisable

to use the discharge points in order that the remaining sections will tend to flash over rather than puncture.

It is not advisable, however, to obtain a very high factor of safety in this way, otherwise there may be too many spill-overs on the line, causing interruptions which may be even more serious than punctures where the discharge points were not used.

It becomes more apparent every day that a transmission line is like a chain in that it is no stronger than its weakest links, and if we are to improve operation we must give the factors governing these weak links proper consideration.

Improved mechanics in the insulator and test methods will do much to improve the reliability and life of future lines, as there seems to be little or no depreciation in the material where there is a good margin of safety.

It must be remembered that even a slight degree of insulator depreciation produces an operating hazard through the matching up of weak parts, and may cause trouble, whereas a much higher degree of depreciation on other parts or apparatus on the system may cause no interruption, nor give any direct evidence, and may be overlooked. Even with the high working stresses set up in the dielectric, it is doubtful if insulator depreciation is much, if any, greater than that of much of the other apparatus on the system, and attention to the factors causing trouble through depreciation will do much to improve operation of present or future systems.

To be presented at the 302d Meeting of the American Institute of Electrical Engineers, New York, December 11, 1914.

(Subject to final revision for the Transactions.)

EFFECT OF ALTITUDE ON THE SPARK-OVER VOLTAGES OF BUSHINGS, LEADS AND INSULATORS

BY F. W. PEEK, JR.

ABSTRACT OF PAPER

The dielectric strength of air decreases with decreasing pressure and increasing temperature; that is, with the density. Therefore, at high altitudes where the barometric pressure is low, brush discharge starts and spark-over takes place at lower voltages than at sea level. The effect of air density on corona, and spark-over between spheres, etc., has already been given.

In the following investigation the effect of altitude and temperature on the surface spark-over of leads and insulators was studied by placing them in a large wooden cask and gradually exhausting the air. Correction factors are given for various standard types. The spark-over voltage decreases almost directly with the air density.

The following gives an idea of the magnitude of the correction: The spark-over voltage of a certain string of insulators at 25 deg. cent. is

Kv.	Altitude	Possible Location
300	0	Sea level
250	5,000 ft.	Denver
205	10,000 ft.	Colorado

THE following investigation was made to determine the effect of air density, and therefore of altitude or barometric pressure, and temperature, upon the spark-over voltages of leads, insulators, etc.

The dielectric strength of air decreases with decreasing pressure and increasing temperature; that is, with the relative density or with the average spacing of the molecules. If the relative density is taken as unity at a standard pressure of 76 cm. and a temperature of 25 deg. cent., the relative density at any other pressure and temperature is

$$\delta = \frac{3.92\, b}{273 + t}$$

where b = barometric pressure in cm.

and t = temperature in degrees cent.

For the uniform field between parallel planes the spark-over voltage decreases directly with δ. If e is the spark-over voltage for a given spacing at $\delta = 1$, the spark-over voltage e_1 at $\delta = 0.5$ is

$$e_1 = 0.5\, e$$

The effect is the same for the same value of δ whether δ is changed by temperature or by pressure. This has been shown elsewhere.* For non-uniform fields, as those around wires, spheres, insulators, etc., the spark-over voltage decreases at a lesser rate than the air density. The theoretical reasons for this have been given, as well as the laws for regular symmetrical electrodes, for cylinders, and spheres.†

It is, however, not possible to give an exact law covering all types of leads, insulators, etc., as every part of the surface has its effect. The following curves and tables give the actual test results on leads, insulators, and bushings of the standard types. The correction factor for any other lead or insulator of the same type may be estimated with sufficient accuracy. When there is doubt, δ may be taken as the maximum correction. It will generally be advisable to take δ because the local corona point on leads and insulators will vary directly with δ. This is so because the corona must always start on an insulator in a field which is locally more or less uniform.

The tests were made by placing the leads or insulators in a large wooden cask 2.1 meters high by 1.8 meters inside diameter, exhausting the air to approximately $\delta = 0.5$, gradually admitting air and taking the spark-over voltage at various densities as the air pressure increased. The temperature was always read, and varied between 16 and 25 deg. cent. The cask is shown in Fig. 1.

At the start a number of tests were made to see if a spark-over in the cask had any effect upon the following spark-overs by ionization or otherwise. It was found that a number of spark-overs could be made in the cask with no appreciable effect. During the test, the air was always dried and the surfaces of the insulators were kept clean.‡

Table I is a typical data sheet. Tables II to VI give even values of δ and the corresponding measured correction factors. If the spark-over voltage is known at sea level or $\delta = 1$ (76 cm. bar., temperature 25 deg. cent.) the spark-over at any other value of δ may be found by multiplying by the corresponding correction factor. It will be noted that in most cases the correction factors are very nearly equal to δ.

**Law of Corona II*, A. I. E. E. TRANS., 1912, p. 1051.

†*Law of Corona II*, A. I. E. E. TRANS., 1912, p. 1051, and *Law of Corona III*, A. I. E. E. TRANS., 1913, p. 1767.

‡In these tests, corrections have been made for wave shape, etc., and the voltages checked by *sphere gap*. Voltages measured by needle gap are incorrect and indicate higher voltages than really exist.

[PEEK]

FIG. 1—CASK FOR STUDY OF VARIATION OF SPARK-OVER AND CORONA VOLTAGE WITH AIR DENSITY OR ALTITUDE

TABLE I

SUSPENSION INSULATOR

Bar cm.	Vac. cm.	Pressure cm.	Temp. cent.	δ	Kilovolts arc-over
75.4	37.4	38.0	22.	0.50	121.0
"	34.3	41.1	"	0.54	131.0
"	30.0	45.4	"	0.60	144.0
"	26.4	49.0	"	0.65	158.5
"	23.0	52.4	"	0.70	165.0
"	19.3	56.	"	0.74	177.5
"	17.5	57.9	"	0.77	183.2
"	15.0	60.4	"	0.80	195.0

TABLE II

LEADS. (See Fig. 17)

δ	Correction Factor for Lead Shown in			
	Fig. 2	Fig. 3	Fig. 4	Fig. 5
1.00	1.00	1.00	1.00	1.00
0.90	0.92	0.91	0.92	0.92
0.80	0.83	0.82	0.83	0.85
0.70	0.74	0.72	0.75	0.77
0.60	0.70	0.65	0.64	0.66
0.50	0.61	0.56	0.54	0.57

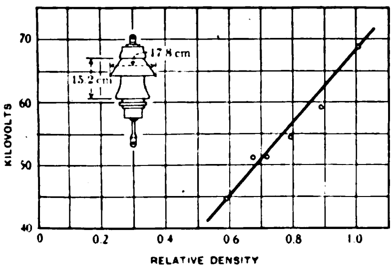


FIG. 2—ARC-OVER VOLTAGES AT VARIOUS DENSITIES

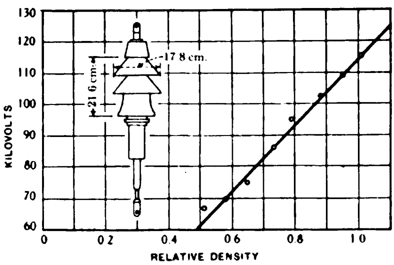


FIG. 3—ARC-OVER VOLTAGES AT VARIOUS AIR DENSITIES

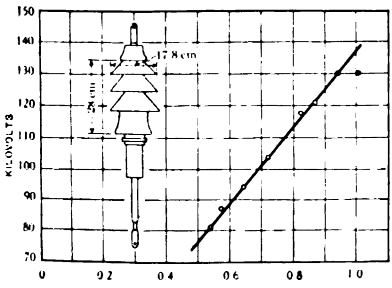


FIG. 4—ARC-OVER VOLTAGES AT VARIOUS DENSITIES

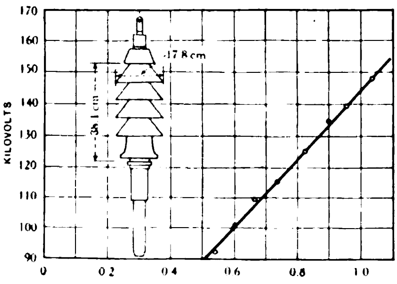


FIG. 5—ARC-OVER VOLTAGES AT VARIOUS DENSITIES

TABLE III

Post and Pin Insulators. (See Fig. 20)

δ	Correction Factor for Insulator Shown in		
	Fig. 6	Fig. 7	Fig. 8
	Post	Pin	
1.00	1.00	1.00	1.00
1.90	0.93	0.91	0.94
0.80	0.84	0.81	0.86
0.70	0.76	0.73	0.75
0.60	0.68	0.62	0.65
0.50	0.60	0.52	0.53

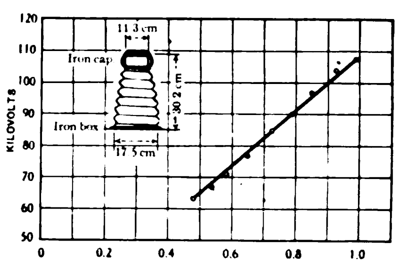


Fig. 6—Arc-Over Voltages at Various Air Densities.

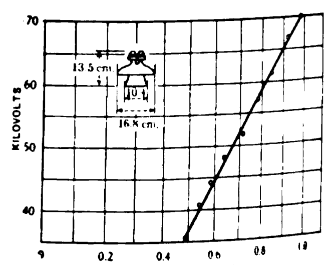


Fig. 7—Arc-Over Voltages at Various Densities

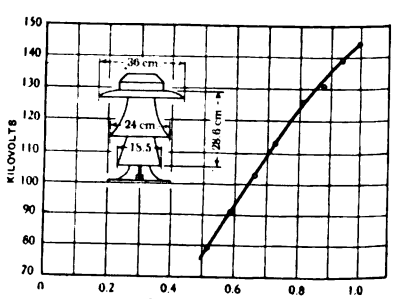


Fig. 8—Arc-Over Voltages at Various Densities

TABLE IV

SUSPENSION INSULATOR FIG. 9. (See Figs. 18 and 19)

δ	Correction Factor for Units in String as follows — Number of Units 1	2	3	4	5
1.00	1.00	1.00	1.00	....	....
0.90	0.96	0.93	0.90	....	....
0.80	0.91	0.84	0.80	....	....
0.70	0.86	0.76	0.70	....	....
0.60	0.80	0.66	0.60	....	....
0.50	0.72	0.55	0.50	....	....

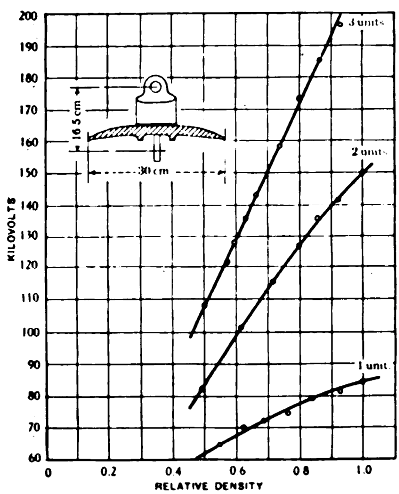


FIG. 9—ARC-OVER VOLTAGES AT VARIOUS AIR DENSITIES

TABLE V

SUSPENSION INSULATOR, FIG. 10. (See Figs. 18 and 19)

δ	Correction Factor for Units in Strings as follows				
	Number of Units				
	1	2	3	4	5
1.00	1.00	1.00	1.00	1.00	1.00
0.90	0.95	0.91	0.90	0.90	0.91
0.80	0.89	0.81	0.81	0.81	0.82
0.70	0.80	0.72	0.72	0.72	0.73
0.60	0.70	0.63	0.63	0.63	0.65
0.50	0.57	0.53	0.53	0.53	0.57

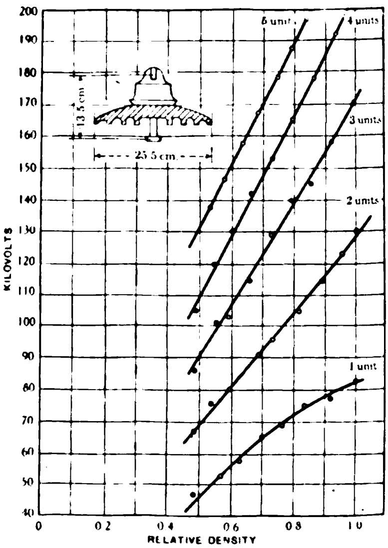
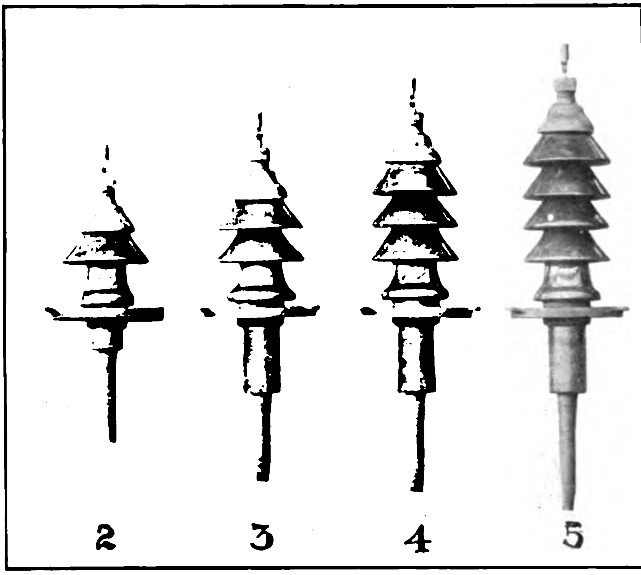


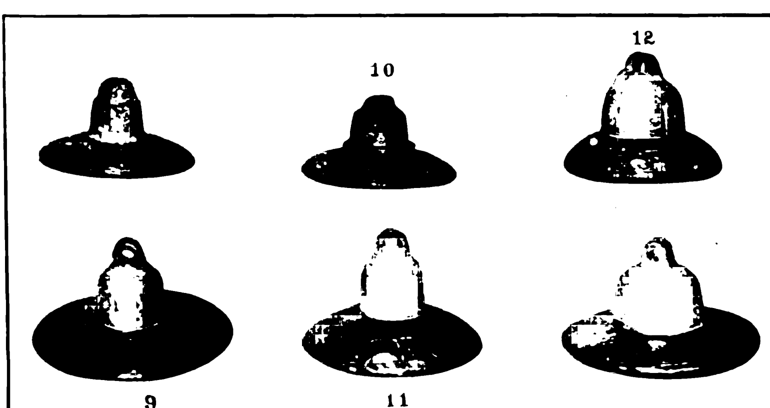
FIG. 10—ARC-OVER VOLTAGES AT VARIOUS AIR DENSITIES



[PEEK]

FIG. 17—SPARK-OVER TAKEN ON UPPER PART OF LEAD—LOWER PART IN OIL

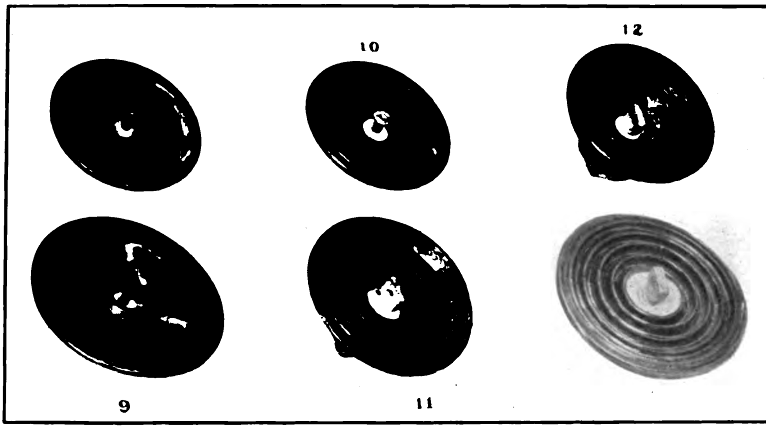
Numerals refer to figure number of data curve.



[PEEK]

FIG. 18—TYPES OF PORCELAIN INSULATORS TESTED AT VARIOUS AIR DENSITIES

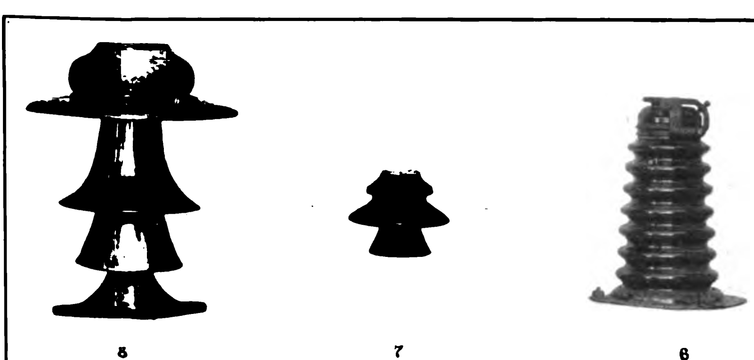
Numerals refer to figure number of data curve.



[PEEK]

FIG. 19—TYPES OF PORCELAIN INSULATORS TESTED AT VARIOUS AIR DENSITIES

Numerals refer to figure number of data curve.



[PEEK]

FIG. 20—TYPES OF PORCELAIN INSULATORS TESTED AT VARIOUS AIR DENSITIES

Numerals refer to figure number of data curve.

TABLE VI

SUSPENSION INSULATOR, FIG. 11. (See Figs. 18 and 19)

δ	Correction Factor for Units in Strings as follows				
	Number of Units				
	1	2	3	4	5
1.00	1.00	1.00	1.00	1.00	....
0.90	0.94	0.92	0.90	0.90	....
0.80	0.87	0.84	0.80	0.80	....
0.70	0.81	0.73	0.70	0.70	....
0.60	0.72	0.63	0.60	0.60	....
0.50	0.62	0.52	0.50	0.50	....

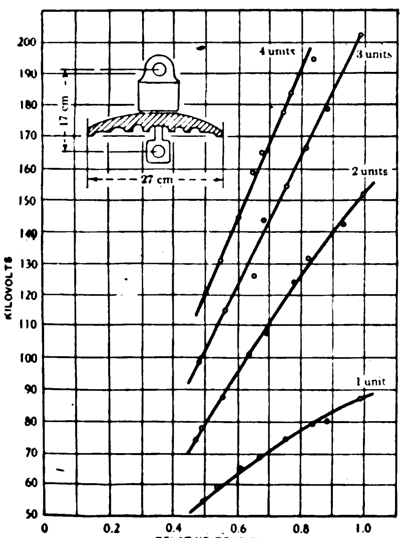


FIG. 11—ARC-OVER VOLTAGES AT VARIOUS AIR DENSITIES

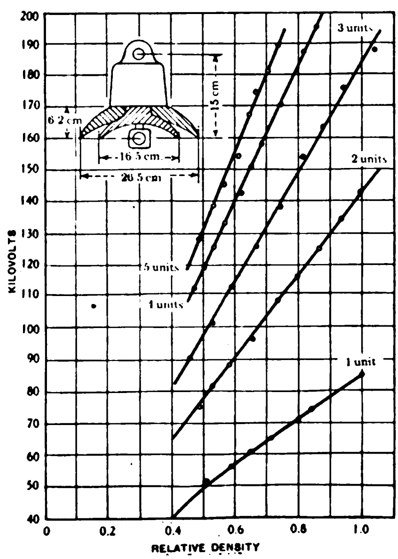


FIG. 12—ARC-OVER VOLTAGES AT VARIOUS AIR DENSITIES

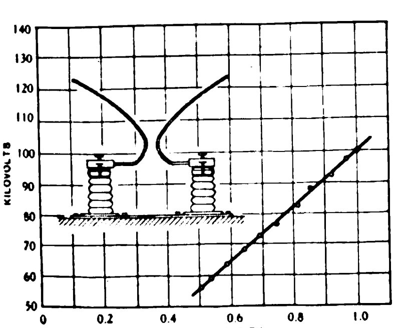


FIG. 13—ARC-OVER VOLTAGES AT VARIOUS AIR DENSITIES

Horn gap spark-over. Gap spacing 14 cm. Diameter of horns 1.27 cm.

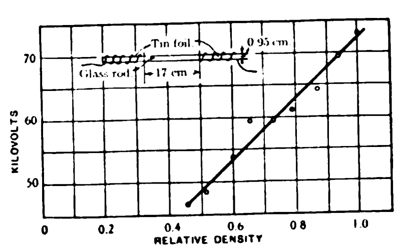


FIG. 14—ARC-OVER VOLTAGES AT VARIOUS AIR DENSITIES

Fig. 15 is a curve giving different altitudes and corresponding δ at 25 deg. cent. If the spark-over voltage is known at sea level at 25 deg. cent., the spark-over voltage at any other altitude may be estimated by multiplying by the corresponding δ, or more closely if the design is the same as any in the tables, by the correction factor corresponding to δ. If the local corona starting point is known at sea level, it may be found for any altitude by multiplying by the corresponding δ. The barometric pressure corresponding to different altitudes is given in Fig. 16. Figs. 17 to 20 show the insulators used in these tests.

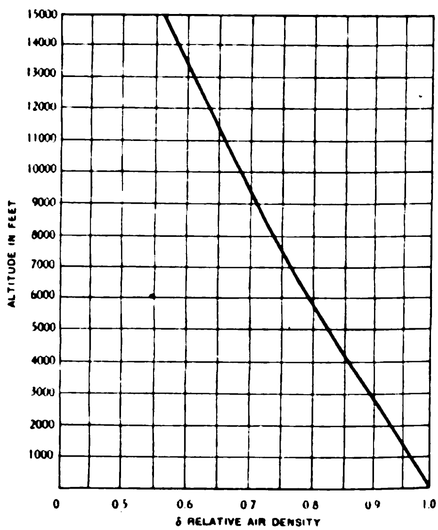


FIG. 15

As an example of the methods of making corrections: assume a suspension insulator string of four units with a spark-over voltage of 205 kv. (at sea level, 25 deg. cent. temperature). $\delta = 1$. What is the spark-over voltage at 9000 ft. elevation and 25 deg. cent.?

From Fig. 15, the δ corresponding to 9000 ft. is

$$\delta = 0.71$$

Then the approximate spark-over voltage at 9000 ft., 25 deg. cent. is

$$e_1 = 0.71 \times 205 = 145 \text{ kv.}$$

If this happens to be the insulator of Fig. 10, the correction factor corresponding to $\delta = 0.71$ is found in Table V, by interpolation, to be 0.73. The actual spark-over voltage for this special case is

$$e_1 = 0.73 \times 205 = 150 \text{ kv.}$$

The first estimate is on the safe side and close enough for all practical purposes. Thus, for practical work the correction may generally be made directly by use of Fig. 15.

The spark-over voltage of an insulator is 100 kv. at 70 cm.

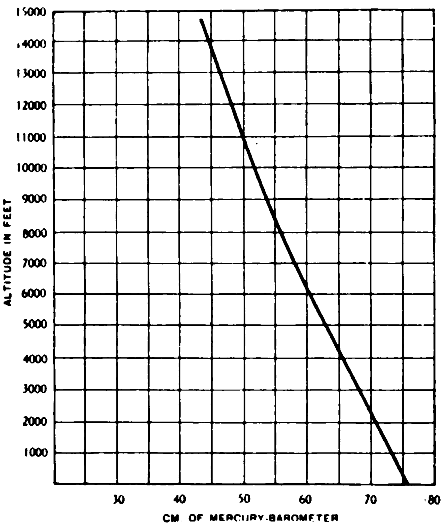


FIG. 16

barometer and 20 deg. cent. What is the approximate spark-over voltage at 50 cm. barometer and 10 deg. cent.?

$$\delta_1 = \frac{3.92 \times 70}{273 + 20} = 0.94$$

$$\delta_2 = \frac{3.92 \times 50}{273 + 10} = 0.61$$

$$e_1 = 100 \times \frac{0.61}{0.94} = 65 \text{ kv.}$$

If the local corona starting point is known at, say, sea level, it may be found very closely for any other altitude by multiplying by the correction δ.

The spark-over voltage of insulators will vary somewhat from day to day, due to humidity. There is also some variation for different units. The humidity voltage variation on the insulator i[illegible] as high as 7 per cent, from day to day. Comparative [illegible] types, when desired, should be made at the same t[illegible] [illegible]idity correction, on the insulator itself, is too complicated [illegible] and of no practical value. Care must be taken, however, [illegible] a measuring gap unaffected by humidity; that is, a sphere gap.

DISCUSSION ON "DIRECT-CURRENT MOTORS FOR COAL AND ORE BRIDGES" (McLAIN), DETROIT, MICH., JUNE 23, 1914. (SEE PROCEEDINGS FOR JUNE, 1914.)

(Subject to final revision for the Transactions.)

D. B. Rushmore: There is a fairly sharp dividing line which distinguishes motor application work from other fields of engineering, except railway work, which must be considered as a specific field in itself. The field of motor application is very largely that of driving machines which either perform work themselves or are very actively connected with the work performed, and machines engaged in conveying material.

In every case of motor application the first thing we start out with is the duty cycle, the load curve of the work to be performed. Then we have, after proper consideration has been given to the subject, all the different electrical motors available, the selection to be determined by the characteristics of the machine involved. These are the two things which have to be fitted together, and with them goes also the question of controller, hand control or automatic control. These questions resolve themselves always into a consideration of these factors: the starting torque, the heating of the motor, the necessary relation between the control and the duty cycle, and the questions of capacity, of speed, and of energy consumed.

Another field, that of conveying material, is being opened up in one way—that is, the handling of bulk material has been fairly well worked out, when we consider coal, sand, ore, grain, and similar commodities. The handling of the other class of material, the package material, has not been solved to any considerable extent, and this is one of the largest fields that is open at the present time for electrical and mechanical engineers to work on.

It is very interesting to see how the different factors involved in the class of problems dealt with in Mr. McLain's paper change in the order of their importance. With a big ship waiting to be unloaded, speed might become a more important factor than any other consideration, and in conjunction therewith the factor of proper speed control in order to obtain the maximum capacity. In other cases, where the energy consumed is very large and the cost of power a considerable proportion of the cost of the final product, the problem would be considered from a different viewpoint.

S. C. Lindsay: I ask the author whether we are to infer that braking has usually been accomplished by electrical means, or whether they have tried out and discarded frictional brakes operated by air or magnetic devices.

T. E. Tynes: Some very interesting control problems come up in connection with ore bridges. We have on our bridges two 230-h.p. motors which are used not only to hoist, but to move the bridge back and forth, down the track, over the different piles of ore. We run the bridge up and down the track with the motors in series. On the hoist we use them in parallel,

or multiple. We use dynamic braking on the lowering, but with only one of the motors on dynamic braking, *i.e.*, having only one motor perform the dynamic function. We had to do some scheming to get the arrangement of contactors which would allow us to hoist in multiple, and also use dynamic braking with one motor, but it can be done, and done very nicely.

R. H. McLain: In all large hoists of 5-ton bucket capacity and greater, I think I am perfectly safe in saying that dynamic braking is used, for the reason that friction brakes large enough to stand the wear and tear would take up too much room and be too expensive to maintain. That seems to be the present attitude of those designing these bridges. For smaller hoists this is not so generally the case. It is sometimes a matter of opinion, but I believe the most popular way is to use dynamic braking. Sometimes dynamic braking is used on the hoist motion alone and not on the racking motion, and at other times on both motions. The present status of the art was arrived at by a lot of trials with various ways of handling brakes. Of course, on hoist motion they always have mechanical brakes to sustain the load, but not necessarily to lower it.

DISCUSSION ON "CONCATENATED INDUCTION MOTORS FOR ROLLING MILL DRIVE" (OSCHMANN), DETROIT, MICH., JUNE 23, 1914. (SEE PROCEEDINGS FOR JUNE, 1914.)

(Subject to final revision for the Transactions.)

Rudolph Tschentscher: The three points which stand out very prominently to me as a steel man are these: First, the exceptional reliability of the equipment—it entailed a loss of a little over one hour's time in practically a year's operation; second, the low operating cost, there being no additional attendance required; and third, probably greater than either of the other two, the rapidity of the control movement. I think the paper gives the time for braking, reversing the forward motion, as being done within one minute. That, to one in the steel business, means a very considerable saving in tonnage.

T. E. Tynes: One of the experiences that probably all steel mill men have had, is that when you ask the management to put in new equipment, they come back to you with the argument "The first thing you will want is a spare unit to take care of that in case there is a breakdown." I am glad to note the reliability of this set Mr. Oschmann has just described. Probably it does not need a spare unit. I see no reason why, in the modern mill motor and the modern equipment the manufacturers are giving us, we cannot say we have as reliable apparatus as the steam engine.

A. E. Averrett: I would like to mention one feature in concatenated motors. In case of a small reduction in speed, such as 14 or 16 poles concatenated with 4 poles, the efficiency and power factor will remain quite high, but when a speed reduction to $\frac{1}{2}$ or thereabouts takes place the power factor is very much reduced due to the second motor drawing its current through the first motor; the output of both motors being approximately equal. With rheostatic control the power factor would remain high, but the efficiency would go down proportionally to the speed; with concatenated control the reverse takes place, that is, high efficiency, but power factor reduced approximately proportionally to speed. Therefore, large speed reduction by concatenation is at the expense of power factor.

Discussion on "The Electrically Driven Gyroscope in Marine Work" (Ford), Detroit, Mich., June 23, 1914. (See Proceedings for June, 1914.)

(Subject to final revision for the Transactions.)

Alfred E. Waller: There are two points I would like to ask Mr. Ford to explain further. One of them is, just what position the gyro occupies in the ship; for instance, just what is done to it to produce this rolling which has been shown to be so effective in breaking ice and getting a ship through a channel which would otherwise be obstructed?

The other thing I would like to have explained more in detail is this: I understand that the directive force of the gyro is a certain component of the angular motion of the earth, and at the poles this would be zero, so this should render the gyro ineffective at the poles. I would like to know to what extent the gyro is affected by extreme north or south latitudes.

H. C. Ford: The method of rolling the ship simply consists in forcing the precession or oscillation of the gyro about its vertical axis. When the ship rolls, the gyro tends to precess, and if this precession is allowed to occur, resisting forces will be set up proportional to the velocity of precession, which will partially stabilize the ship. To stabilize the ship completely it is necessary so to control the precession in time and amount that the varying wave forces are each counteracted by an equivalent gyroscopic moment. By forcing the precession, energy may thus be transferred through the gyro and the ship made to roll.

The gyro may be located in any convenient space that is available where the necessary bracing can be secured to the frame of the ship. Although the forces are large they are not excessive, being approximately of the same order of magnitude as the wave forces counteracted. It has been found that when stabilized, the ship is subjected to less strain than when allowed to roll freely. This is partly due to the fact that the waves are neither uniform nor synchronous with the roll of the ship. The freely rolling ship rides some waves easily, but frequently gets out of step and crashes into a wave with much greater shock than is the case with the stabilized ship, where the effect of the variable waves is reduced to a moderate average.

The size of gyroscope required to stabilize any ship depends entirely upon the proportions of the ship, which vary greatly in ships of a given tonnage. The gyro designed for the steamship *Ashtabula* is much larger than would be required for other ships of the same displacement, which would ordinarily have a smaller metacentric height. It may seem strange that the flatter, the more stable, a ship is, the more it will roll in a heavy sea, while a ship proportioned more like a cigar, with a low metacenter, will not roll, although it might capsize. The latter could be effectively stabilized with a very small gyro. The weight of the gyro installation required for any particular case cannot be given without quite extensive calculations.

DISCUSSION ON "ELECTRIC HEATING AS APPLIED TO MARINE SERVICE" (McDOWELL AND MAHOOD), DETROIT, MICH., JUNE 23, 1914. (SEE PROCEEDINGS FOR JUNE, 1914.)

(Subject to final revision for the Transactions.)

W. S. Hadaway, Jr.: The paper by Messrs. McDowell and Mahood is of value in showing that while different types of heaters develop the same amount of heat with the same input, their effective value may vary according to conditions of service.

The *Electrical Engineer*, New York, January 20, 1897, published tests on "Incandescent Lamps vs. Commercial Heaters." The authors were E. Y. Young and C. D. Warner, and the tests embodied a series of experiments at the University of Nebraska, in the spring of 1896.

The apparatus tested for a commercial electric heater was a 3½-h.p. car heater of the Wittingham make. The heater consisted of twelve wrought iron tubes, 1 in. in diameter, 6 ft. long, and had a total radiating surface of 2592 sq. in. Each tube carried three strands of No. 20 B. & S. German silver wire twisted together, and inserted in a ¼-in. glass tube, the whole being then filled in with clean sand.

The room in which the test was made was 10 ft. long, 7 ft. 9 in. wide, 16 ft. 8 in. to the plate, and 19 ft. 2 in. to the ridge, giving a total volume of 1396 cu. ft. With the commercial heater, the mean temperature of room at the beginning was 19 deg. cent. and the mean temperature of the room when the current was shut off was 35.55 deg. cent., or a mean temperature rise of 16.55 deg. cent.

The incandescent lamps were grouped in a bank of 75, 16-c.p., 110-volt lamps, arranged in three parallel rows. The heater had approximately the same dimensions as the car heater, and was tested under similar conditions. The mean temperature of the room at the beginning with the lamps was 19.3 deg. cent., and the mean temperature when the current was shut off was 35.85 deg. cent., showing a mean temperature difference of 16.55 deg. cent., or the same value as obtained with the Wittingham car heater. The only difference in the results is in the rate of temperature rise. It is shown graphically in the paper for purposes of better comparison.

From Fig. 9, in the McDowell and Mahood paper, it would appear that it was possible to heat an outer state room, with the same amount of energy, more rapidly than an inner state room. In view of the fact that the findings are modified by the peculiar shape of the room as shown in Fig. 8, it would seem desirable to state that the shape of the rooms has more to do with these results, than their location.

The only point to which we take exception, is the fact that the authors are assuming a somewhat extreme position in reporting that the tests on the radiant heaters indicate a less effective structure than the convector type. While the curve in Fig. 10 seems to confirm this position, it would be desirable to carry

out the tests more carefully, and for longer periods of time, to confirm this conclusion.

The general conclusions as to the adaptability of electric heaters in marine service are encouraging. The modern ship is an industrial power installation of the most compact type, and the improvement in load factor by a mixed heating and cooking load would make an investigation of additional interest.

Alfred E. Waller: The curves shown in this paper, so far as rapidity of obtaining heat is concerned, appear to indicate a certain amount of advantage in favor of the open wire coil heater. It is my belief, however, that the advantages obtained by using heaters with entirely protected coils more than offset the slight advantage gained in the quick heating of the open coil type.

Enclosed or protected resistances can be made to reach their maximum temperature almost, if not quite, as quickly as the open type, and the extra time required to reach this maximum temperature is relatively unimportant if we compare it with the total time the heater is in use.

Suppose, for instance, that an open coil heater emits heat at the required rate twenty minutes after the switch is closed, and an enclosed heater takes forty minutes under the same conditions. This is an extreme case, and does not by any means represent the best performance to be obtained with the enclosed type heater. Under these circumstances, if the heaters are run for twelve hours, one takes 1/36 and the other 1/18th of the total elapsed time to reach full heat.

Disregarding this question of initial heating until it can be further investigated, I recommend the use of heaters with fully enclosed or protected resistors, for the following reasons:

Heaters are designed with two main objects in view—the first, that they shall give off heat, and the second, that they shall continue to operate for the maximum possible length of time with the minimum of repairs and replacements of units. It seems therefore very necessary that the resistance element should be protected in some manner, so that the moisture encountered in marine service shall not come in contact with the resistance.

A protecting layer of insulating and heat-conducting material, placed around the resistance wire or ribbon used in a heater, may be so arranged that it will not only exclude moisture, but will also protect the resistance material against chemical depreciation or mechanical injury of any kind. The support given the resistance element throughout its entire length is another advantage.

The possibility of short circuits, grounds, and dropping of molten metal which may occur as a result of burnout in an open coil resistance will be readily appreciated. In a properly designed unit of the enclosed type, this danger is entirely eliminated.

One objection which has been urged against the enclosed type is that the weight is greater than that of an open type resistance.

This is not necessarily true, for the enclosed type resistance unit may be made considerably smaller than the open type, even if the total area of each heating unit is the same. This is because open coil units must be made of wire much heavier than is necessary in constructing an enclosed type unit, in order that the resistance may be mechanically strong enough to stand up in service.

I believe there is room for considerable investigation along one or two lines. One of these is whether it is not possible to use an enclosed type resistance run at a relatively high temperature, and to surround this by baffle plates or deflectors, which will cut off the radiant heat referred to by the authors, and at the same time permit a compact, mechanically strong and adequately protected unit to be used.

Another point which occurs to me, is the outside paint or covering on the heater. Dr. Carl Hering has published a number of discussions in the last few years on the general subject of surface resistance to thermal flows. These articles emphasize the influence which the outside surface of a body has upon the convection and radiation of heat. Related to the same subject is a paper presented by Dr. Irving Langmuir before the American Electrochemical Society. In this he discussed the effect of a polished silver surface.

Another interesting example is a foundry of which I have heard, in which the workmen whitewashed the outside of the furnaces, because they were then able to work near them in more comfort. The whitewash apparently had the effect of producing a high contact resistance between the furnace and the surrounding air, and the heat loss by radiation from the outside of the furnace was reduced.

The temperature of the outside of this furnace was found to be several degrees higher after the whitewash had been applied, this being the result of stopping part of the emission of heat by radiation.

It is an interesting paradox, if we consider two furnaces of exactly the same type and size, operating at the same internal temperature, one whitewashed and the other not whitewashed. In this case, the furnace with the hotter exterior would be operated with the greater efficiency—a condition which appears unreasonable until the attendant conditions are known.

Charles D. Knight: There are a few points I would like to draw attention to in connection with the paper. First, it is my opinion that the convector type of heater is much more efficient than the radiant. I also agree with the authors that it is better to heat a large volume of air to a few degrees than a small volume to a proportionately greater number of degrees. This is probably more important in the heating of houses than battleships, due to the fact that curtains, draperies and other material may come in contact with the heater.

The authors very clearly defined the amount of power required to heat a room of a certain area, and this brings up the

question of the very large gap that the power companies have to cover in reducing the price of power per kilowatt-hour. The authors have said that power can be generated in battleships for one cent per kw-hr., and I have no doubt but what the power companies can also do this, but when you consider the maintenance of the lines, and the expense of running them throughout the city over great distances, the cost becomes much greater.

When we figure out an ordinary size house, we will say with 20,000 cu. ft. of volume, we know that with hot air, hot water or steam it can be heated for $125 a year. Some rough figures, which I have made, will show that electricity at 5 cents per kw-hr. would cost very nearly $2,000 a year, and at 1 cent per kw-hr. about $400. It can readily be seen what the electrical engineer has to do in the matter of reducing cost of power to meet the competition which I have just mentioned.

D. B. Rushmore: I think it would be interesting, as this paper goes on record and is necessarily read by people outside of the Institute, if the authors will put in a little explanatory clause, as to how they calculate the cost of power on the battleship. That is a matter which is often misleading to people who are not familiar with the subject. I presume they leave out the original investment in the boilers and tanks, which would occur in a central power station. As an illustration, a man can raise coffee in Brazil, we will say, for five cents a pound, just as he can generate a kilowatt-hour, under certain conditions, we will say, for one cent, but the expense of getting the coffee into the hands of the consumer is what runs up the cost. It must be taken to the ship, brought to the country of consumption in the ship, then transferred to the wholesale houses, thence to the distributors, thence to the grocers, thence into the pantry at your home, which will probably cost about 35 cents per lb., and, therefore, you pay 40 cents per lb. for the coffee. That is the rough figure, but the figure on the cost of power is so disturbing to public utility companies just now, that unless an explanation is put in as to how this cost on the battleship is arrived at, the statement is apt to cause some misconception.

F. C. Caldwell: There is a very general idea that the radiant heater is too expensive in current consumption for common use in residences. The radiant projection of the heat directly upon the body to be warmed, however, makes it much more economical than is ordinarily supposed, and it is a great source of comfort as an auxiliary means of heating in a room where persons only occasionally gather. The absence of time lag in the effect obtained from a radiant heater adds greatly to its usefulness for such occasional duty.

We have found during the past year that the most appreciated electrical appliance in our household is an electrically heated blanket, or quilt, which consists of an ordinary bed-size quilt with a resistance wire woven all through it. This makes all the difference between comfort and pretty strenuous existence in outdoor sleeping, when the temperature is about zero. It

is something which should be used and appreciated much more than it is at the present time.

D. M. Mahood: I will take up the important points in the order in which they were presented, and comment on them as briefly as possible. Mr. Hadaway called attention to the variation in the curves in Fig. 9. We intended in that curve to show only the comparison between the bare resistor and the enclosed unit, and not a comparison of the heating of the inner and outer staterooms.

Mr. Waller commented on the comparison between the open and closed type of unit. Where it is possible to install an open rheostat without danger on a battleship, we can, of course, install a bare unit, but we would not think, for instance, of putting an open type of unit into a powder magazine or anything like that. It is the old story of adaptability—you must consider the conditions of the installation as well as the design of the material you are installing.

Mr. Knight and Mr. Rushmore both commented on the cost of power. The cost of ship-generated power, 1 cent per kw-hr., is the actual cost of generation. It does not take into consideration the cost of installation, depreciation, or the investment. In marine service, we have conditions very different from those prevailing in land work. We have the boilers, of necessity, for the purpose of propelling the ship, and the additional load for electric heating is small on the generating plant, and fits in very nicely with the other loads, the power and the lighting, and really, as a matter of fact, runs the boilers at a slightly better efficiency load.

Mr. Caldwell made reference to the radiant heater. The radiant heater is worked at a disadvantage in marine work, because we have the metal bulkheads which conduct off the heat received from the radiator. It is necessary, in order to use a radiant heater, to step right in front of it to get the effect of the heater. It is found that practically but little of the heat is sent off as convected heat, after it strikes the bulkhead—it is practically all conducted off. That brings us down to the convector type. The conditions on land are different. You have the wooden walls, which are poorer conductors, and for that reason the radiant heater has a greater field than it has in marine work.

H. A. Hornor: The battleship situation is one of metal bulkheads solely. In the merchant marine service, where you have the wooden bulkhead, and particularly out on the western coast, the conditions are more satisfactory. We recently built a ship to which we applied the radiant heaters. Practically every stateroom had a radiant heater of the three-unit type, and all public places had special fireplaces of the radiant heater type. It was a pretty effect, and the operation was very satisfactory. The conditions on the Pacific Coast are that the temperature changes are not violent, and the application of the heating apparatus to a passenger steamer was a good one.

DISCUSSION ON "TOLL TELEPHONE TRAFFIC" (FOWLE), DETROIT, MICH, JUNE 26, 1914. (SEE PROCEEDINGS FOR JUNE, 1914.)

(Subject to final revision for the Transactions.)

J. Lloyd Wayne, 3rd: I think this subject of telephone toll traffic is very close to the heart of every operating telephone man and it is certainly to be appreciated if we can bring before the public the fact that speed costs money. The telephone message being largely intangible, the general public is apt to get the idea that it does not make any difference in your cost of operation whether you get the connection through quickly or slowly. The telephone user is liable to forget the simultaneous demands of the many other telephone users. This paper brings out evidence of the practical necessity of lining up the toll calls in the order of receipt, if rates and earnings on the plant investment are to be reasonable. Every toll telephone plant representing a large investment may be likened to a transmission plant subject to very high peak loads. A large part of the day the plant is not carrying anywhere near its capacity and at other parts of the day it may be subject to overload demands. Unfortunately these busy or overload periods occur at the hour when business is at its height and thus at the time when speed means the most to the patron.

Again, with our telephone toll plant the revenue is based on the productive time. Furthermore, with each short period of production we must necessarily have a nonproductive time during which the circuit must be built up from the calling party to his correspondent. It is as though we had a power transmission line, the revenue from which is derived from the number of minutes of useful production of a motor load at one end, it being necessary to stop and start both generator and motor, free of charge, before and after each useful run. It is very evident that the less this nonproductive time, especially at busy periods, the greater the number of messages that can be handled. Mention is made in the paper of the single-ticket and two-ticket methods. The former method cuts down the nonproductive time and gets the business over the line more quickly. However, with the two-ticket method there is a record of the message at two points and thus there is less liability of losing track of completed calls.

The paper calls attention to the fact that with a certain average speed of service, some of the calls will be handled considerably more slowly than the average. This is clearly shown by comparing the curves in Fig. 2 and Fig. 4. The middle curve of Fig. 4 represents approximately 40 messages per circuit. Now if you will observe curve 2, you will find that at this rate the average speed of service as shown by the abscissa is 12 minutes, while the maximum delay shown on the middle curve of Fig. 4 is some 30 minutes, or two and one-half times this. It is well recognized that speedy service is a good advertisement and re-

sults in the filing of many messages which would not otherwise be offered. In devising a telephone toll plant we must continually have in mind the proper balance between (1) the number of messages to be handled, that is, number of paid minutes per day, (2) the necessary speed of service, (3) practicable rates, and (4) the corresponding number of circuits required, that is, the plant investment.

DISCUSSION ON "A HIGH-SPEED PRINTING TELEGRAPH SYSTEM" (KINSLEY), DETROIT, MICH., JUNE 26, 1914. (SEE PROCEEDINGS FOR JUNE, 1914.)

(Subject to final revision for the Transactions.)

C. R. Underhill: Mr. Kinsley is certainly to be congratulated on the very ingenious device which he has brought out, and I must say that it is one of the most surprising forms of high-speed printing telegraph instruments which have come to my notice It seems, however, that it is necessary to use two wires and ground, which makes the line expensive, particularly since the machine is designed, I presume, for long-distance transmission, as that would be the service in which it would apparently have its greatest value, but the use of two wires may not be so detrimental as at first appears. Probably one great reason why the printing telegraph has not been adopted more in this country as compared with European countries is because in foreign countries the telegraph is used for letter writing. Abroad, I understand that it is customary to send a telegram instead of a letter, and for that reason the traffic is increased and the price is brought down.

Some years ago, in 1904, I brought out a printing telegraph which has never been made public except through the patent offices of the world, and which has been kept quiescent for certain reasons which need not be mentioned. My object in bringing out this telegraph instrument was based on the fact that the Morse system is in universal use not only in this country, but abroad, not only for short distances, but for great distances, both for wire and wireless telegraphy, and might be called the universal telegraph system. This instrument to which I refer was so designed that it would print in English characters on a tape, something like a stock "ticker", that is, it would translate from the dots and dashes of the Morse code into type. I had a great deal of difficulty on account of certain letters in the Morse code, *i. e.*, C, O, R, Y, Z. I had no difficulty in making it work on the Continental or Universal code.

There is a point I wish to bring up in connection with the introduction of a machine of this character. The telegraph companies of the United States and Canada are very slow in adopting the Continental or Universal code, although it is used abroad, and in the wireless field. It is not unusual for operators to receive messages in the Continental code and send them out again in the Morse code. On the long trans-continental lines they do use the Continental code, to a certain extent. It has been shown that operators in the wireless field readily learn the Continental code, although accustomed to the Morse code, yet the telegraph companies will not adopt it. There seems to be some inertia there.

I would like to ask what effect the line leakages due to weather have on this instrument. Although Mr. Kinsley stated there is no local battery, I understand a local battery has to be used for holding up the armature, as he explained. I would like to

know whether a careful balance has to be maintained in the magnets. We know the quadruplex will not work well whenever there is considerable leakage on the line on account of the weather. I would like to know how line leakage affects these magnets, and whether adjustments have to be made, locally, when the line current varies.

My experience with the telegraph instrument I mentioned has, I think, an important bearing on the introduction of a machine of this kind. I took it before the high officials of one of the large telegraph companies. They received it very nicely and said it was a very ingenious device, etc., but they led me into the operating room and showed me a man sitting before a resonator, with a sounder in it, the man operating a typewriter and taking the matter down at the rate of about thirty-five words a minute. The official said, "You watch that operator." By chance the operator "broke," took the paper out of the typewriter, made a correction on it, put it back and started typewriting again at the rate of about one hundred words a minute. During this interval he was storing the message in his head. The official said, "You bring us a machine that will dispense with the operator, and we will put it in."

In connection with the matter of the two wires, I wish to add that one of the officials, in speaking of the capacity in connection with any machine, said, "Whenever further capacity is needed, we have plenty of wires running between New York and Chicago, and all we have to do is to tap in on another wire." It may be in a case like that, since they have so many wires, it makes no difference whether you use a single wire or three wires at a time. Incidentally, I might add that a code system like the Morse or Continental is applicable both to wire and wireless, whereas I know of no other system which can be applied to both. I have made my system work on the wireless.

Ralph W. Pope: I was particularly struck with the novelty and ingenuity of the system proposed by Mr. Kinsley. It takes me back to the time when there were objections raised to the printing systems then in use. I first learned to operate the Hughes printing telegraph in 1858, and learned the Morse as a side issue and for amusement. What was amusement then became business thereafter, for the printing instruments were gradually discarded. In the days of the printers, the first being the House, followed by the Hughes, we were very careful about sending out good copy, that was perfectly legible and could be read without difficulty by any one. The House machine was inferior in this respect, for the reason that instead of printing direct from the type it made an impression through a carbon tape onto the paper, and the fine lines of the letters were somewhat blurred and the copy looked smutty, but still it was very good if the tape was kept in good order. The Hughes printer, which followed, printed directly from steel engraved letters, the same as the ordinary type used in printing a news-

paper, while the House was similar to the carbon tape on the typewriter. You see we have made considerable improvements, in that the result of a carbon tape today is better than that we used to get from the House printing tape years ago. Legibility, then, was one of the desirable things, but there was another important feature, important in a negative sense—business men did not like the tape, for the reason that it was not the proper kind of a document to file away, and when I was a private secretary and received these tape telegrams in the course of business, one of the jobs of the office boy was to tear the tape into pieces five or six inches long and paste them on a sheet, so that we could file them away. In those days, as I recall, no effort was made towards producing the "page printer," but today we have page printers. The type wheel shifts along on the shaft, and when it comes to the end of a line it goes back. I am not familiar enough with the experiments of Mr. Kinsley to know whether he has undertaken anything of that kind.

We come then, to this question of legibility, and I notice in the paper the author says that the letters and figures can be made more perfect by the use of a sixth element. In the samples presented by Mr. Kinsley it does not seem to me that the figures, more especially, are sufficiently distinct. Figures in a telegram are quite important; I do not refer so much to figures in the body of the message, making errors in reading quotations, for instance, but in the addresses on messages; and the number on the street is not so important as the number of the street itself. Because, if you have a telegram addressed to the right street you are quite likely to find the right number. I have noticed the figures 168, as they appear on this slip. In Washington, that might be read, possibly, 16 B street, or in New York it might be read, instead of 168th street, 108th street, not by an expert, but by the boy who addresses the envelope. So that it appears to me that the figures should be so perfect that there is no possibility of there being errors made in reading them. That is, as you will see, more important than the matter of letters.

For more than forty years, experimenting has been going on with systems of rapid telegraphy. That has always meant the preparation of the message in advance by perforating paper, and running it through rapidly, in order to get this high speed of 650 words a minute. That means that the sending matter must be divided up amongst a few "punchers," as they are called, whereas with the Kinsley instrument, when the message is ready for delivery, it has gone through no other process at the receiving end, and the tape is supposed to be ready to deliver. That has not been the case heretofore with these received messages, they had to be divided up and recopied, on the same principle that they were divided up for punching. While it is desirable, perhaps, to get this high rate of speed, there is another question to be considered, which was brought to my attention

by Sir William Preece at our meeting in April, 1907, when we discussed the Rowland printing telegraph. Sir William said that one of the difficulties they had with these fast systems in England was to get business enough to work the system up to its capacity. There were only a few through trunk lines between London and Liverpool, and London and Glasgow, perhaps, where they could work these fast systems economically, for the reason they would run out of business and would have to wait for more.

I consider that telegraphy, when you recognize its value, is one of the cheapest things we have, but the average individual rarely sends a telegram on his private account. It is only the great business houses, especially brokerage houses in the large cities, which spend such large amounts in telegraphing. I have gone sometimes from one year's end to the other without sending a private telegram, but that is more especially the case since we have had the telephone. So that the cost of telegraphing is a very small item in the expenses of the average consumer.

Years ago I wrote an editorial on this subject, and took for my text the cost per ton of making stoves in Troy. I happened to run across this list of items that went to make up the cost of a ton of stoves—so much for iron, so much for labor, and so on, running up, as I recall it, to about $80 a ton, while for postage and telegraphing, which were lumped together, it was $1 in the cost of a ton of stoves, and bad debts were placed at $2, so that really this amount of bad debts was double the cost of telegrams and letters.

I have always maintained that telegraphing should not be cheapened. This also was an argument put forward by Mr. Swain, who was one of the officers of the first telegraph company in the country, I think, at Philadelphia, when he said they were making a mistake in trying to cheapen the work of the telegraph.

Before typewriters were used it was considered necessary that every operator should write a clear hand, not necessarily handsome, but plain. It is now obligatory, in most offices, to use a typewriter for transcribing messages instead of longhand. So, we have seen an evolution, even in the simple Morse, first from the use of a metal type notched, for transmitting purposes, set up in a stick and run along, because the inventor thought the operator could not make the signals plainly enough. Then we went to the key sending and received messages on the tape. Then the embossing register was discarded, when the operators discovered they could read the signals by sound and do it much more quickly, and more accurately, and keep up with the sender. That is one thing you lose in any system of the kind under discussion, you lose that time which is required in punching the tape. In receiving by sound, ordinarily the operator is close up with the sounder; to be sure, as the previous speaker has said, they may lag behind for a dozen words, and catch up later—that is one of the peculiar features of Morse telegraph-

ing, the ability of the operators to carry along, some of them twelve or twenty-five words, perhaps, behind the sounder and keep these words in memory, while they are turning their carbon sheets, or putting in fresh carbon sheets, and the various other details which are necessary. That is what I used to do when I had to wait on myself and was fixing up carbon sheets for three copies. While I was doing that, the sounder was going on, and when I began the next page I would be a dozen words behind and then would catch up, and be ready to change the next page.

I was speaking of the evolution of the Morse simply by the practical experience and growing skill of the operators. I might say there was always a rivalry between the sending operator and the receiving operator, as to which could work the faster, whether the sending operator could send faster than the receiving operator could receive it, and it was about neck and neck until the typewriter operator arrived. When the typewriter came, the receiving operator had it all his own way, he could almost take a nap in between times, because he could take ten or fifteen words more per minute more than the sending operator could send.

What has happened now? The telegraph company has eliminated all of the conventional signals, formerly required in sending messages. They used to put "ahr" for "another," and "fm" for "from" on our messages. Now, the company, to save time, has eliminated these things, and the receiving operator must be still more expert, because he has no breathing spell. As the operators found they could receive much faster with the typewriter, the company said, "If you can receive so much better by typewriter, you must all do it." So they all do it. The typewriter is in practically universal use today.

We have seen that the receiving operator has more leeway with the use of the typewriter, but in press reports the Phillips code is used by the sender. The Phillips code is an authorized system of abbreviation. This does not apply to the ordinary messages, which are not allowed to be abbreviated. I will give this instance of one word—"scotus." This means the Supreme Court of the United States. When a man receives the word "scotus" over the wire, on his typewriter he must write out the words "the Supreme Court of the United States." That is rather an extreme instance, but it is an example—"scotus" is made up of the initials of the words. The code is copyrighted by Walter P. Phillips, the inventor, and is published in book form.

A word about the present Morse alphabet. It is a very simple matter for an operator to send or receive by either code if he is familiar with them, just as it is easy for Mr. Mailloux, for instance, to state a proposition in nine different languages, so that it is simply a question first, of the Morse operator learning the Continental code, as it is called, which is a very simple matter. It is now required in the wireless service. It would

probably only be necessary for the telegraph companies to say that after a certain date, the first of October, for instance, the Universal alphabet shall be used instead of the Morse. But the question of superiority is not quite settled. When the old Bain chemical telegraph, which was a rival of the Morse, was in operation, the Bain alphabet was used, which by many was considered superior to the Morse, and there were many operators, especially in New England, who knew both alphabets. The Bain code is now obselete.

There is one more question I want to ask of the author. Fig. 7 shows that the dots used for "C" and the dots used for "G" are practically the same, in the case of "G" there being one added, and the same combination of double dots appears in the case of "D." I was a little at a loss to know how the combination came in "I," because the curve is reversed, and I am not certain whether it is possible to reverse the curve or not.

George S. Macomber: I think we should congratulate Mr. Kinsley on his very happy and novel combination of inventions. It seems to me that almost all inventions of this kind are really new combinations of things known before. In the present case we have a type printer operated by electromagnets, combined with an electrochemical telegraph recorder.

All high-speed telegraph recorders may be divided into two general classes, electromagnetic and electrochemical. We have three sub-classes of electromagnetic recorders: (a) those operated by non-timed step-by-step mechanism, as in the case of the various "tickers"; (b) those operated by synchronous motors, as in the case of the Hughes, the Phelps, the Baudot, and the Rowland printers, and (c) those operated by non-synchronous timed impulses, as in the case of the Morkrum printer, in which six electromagnets are successively and automatically operated at definite time intervals after the first or starting impulse is received, and in which the various letter combinations are determined by the arrival or absence of positive or negative current impulses at the receiver as each of the timed magnets respectively operates. We have two sub-classes of electrochemical telegraph recorders: (a) those using undirectional current, as in the early Bain two-wire telegraph; and (b) those using both positive and negative line current impulses, as in the Foote and Randall and the Delaney telegraphs.

Mr. Kinsley's telegraph uses a perforated tape with five rows of perforations somewhat like that of the Pollak-Virag telegraph tape; a transmitter which sends both positive and negative current impulses over the line as did that of Foote and Randall; a two-wire transmission line as did the first Bain system; and a chemically prepared tape similar to that used by Bain and Delaney, in a recorder so arranged as to make, electrochemically, successive lines so placed on the tape as to form or at least imitate type print.

I want to ask Mr. Kinsley how many unit time intervals are required, on the average, by his recorder, per letter. It appears

from Fig. 7 that some letters, as, for example, "B," must require more time than others letters, such as "I".

I wish also to record a correction of the generally accepted notion that Alexander Bain was the first to produce a chemical telegraph recorder, for as early as 1828, Harrison W. Dyer built an electrochemical telegraph recorder and operated it over a line several miles long.

Carl Kinsley: In answering the first question, in regard to leakage and difficulty of balancing, since there is no battery at the receiving end which takes part in the operation of the line current, the battery at the receiving end merely magnetizes the local circuit. In the sending end, is the only battery which takes part in the operation of the line. In instruments with a neutral relay, such as the Edison quadruplex, half a dozen different operations have to be gone through with in order to receive one signal, to quote from "American Telegraphy," by William Maver, Jr., (New York, 1903; page 198):—"it is quite demonstrable that during the making of a dash on the neutral relay at one station the distant pole-changer may reverse its battery several times; the home pole-changer may do l kewise and the home transmitter may increase and decrease the electromotive force of the home battery, repeatedly. At the same time, and, of course, as a result of the foregoing actions, the home neutral relay may have had its magnetism reversed several times, and the signal will have been made, partly by the home battery, partly by the distant and home batteries combined: partly with current on the main line, partly without: partly by the main line 'static' current, and partly by the condenser current, and yet on a well-adjusted circuit it will have been heard on the quadruplex sounder as clearly as any dash on an ord nary 'city line' sounder."

There is nothing of that kind in connection with this instrument. There is merely a positive and negative to line from the transmitter, and it works one particular element, or in one case two elements, and tends to hold up the other one on the line, because these elements are in series with each other; consequently there is no difficulty—any line that is good enough to operate a polarized relay will operate this with current less than is necessary with the usual polarized relay, because the operating energy does not go over the line; the operating energy is supplied largely by the local circuit, and what goes over the line is merely enough to upset the balance between the local magnetic circuit and the tension on the spring.

C. R. Underhill: In case of leakage, could you get enough current to operate satisfactorily?

Carl Kinsley: You can get all that you can from any telegraph line for operating any relay. There is a point where all telegraph lines break down.

C. R. Underhill: Does that come from that kind of balance—in case you had plenty of current, or very little current, would it have to be adjusted to balance?

Carl Kinsley: There is no balancing on the line in that sense. You merely have to arrange the instrument so that it will always operate when the current reaches a minimum value, and it will operate for any value above that. There is no margin of working in that sense.

In regard to the use of six elements, I like the five better, as being more simple to operate. The sixth element will give, possibly, some increase in the beauty of the alphabet, because there can be made certain distinctions with six which cannot be made with five, but, in my opinion, the alphabet made with five elements is perfectly legible. However, if for any reason the five-element method is not sufficiently graceful, then it is possible to use the sixth. As a matter of fact, four elements have been used, and give a legible alphabet to readers familiar with its use, but which lacks the characteristic of being familiar to all.

In regard to Fig. 7, it was suggested that "C" differs from "G" in that there is a second use of the lower half of the vertical line in "G". How that differs from "O" is that there is no second use of the upper half of the vertical line. In the "G" the currents are first positive and then negative over one line, second positive and then negative over the other line, the negative following immediately after positive, and then a wait, and then another negative over the second line. Sometimes there are two impulses in the same direction following each other, but they are followed in the next vertical line by positive and negative. There is no building up of charge in the line, and it has been found that the line can handle two, where it cannot handle five successive impulses in the same direction. This system keeps the line clear for each succeeding letter, starting as it does with positive and negative, which has the effect of clearing the line.

There was another question, I think by the following speaker, asking how many impulses were taken per letter—he said how many "time impulses," I think he meant how many impulses per letter. That varies with the letter. The time element enters into this system—a certain time must be allowed for the receiving tape to get away before printing the succeeding letter. It does not make any difference how many impulses are sent in making a certain letter. The time allowed for a single letter is sufficient for twelve time impulses. As a matter of fact the number of current impulses in that time may only be three or four, but sufficient time must be allowed for the paper to clear. It does not increase the speed to have fewer current impulses, since it is necessary to allow a certain time interval to elapse to give room for the next letter. Twelve time intervals will give sufficient space, and inside of that time there can be as many current impulses as you please, since the positive and negative follow each other and keep the line clear.

DISCUSSION ON "STERILIZATION OF WATER BY ULTRA-VIOLET RAYS OF THE MERCURY-VAPOR QUARTZ LAMP" (VON RECKLINGHAUSEN), DETROIT, MICH., JUNE 26, 1914. (SEE PROCEEDINGS FOR JUNE, 1914).

(Subject to final revision for the Transactions.)

Morgan Brooks: I notice one point, that is not of very great importance, that perhaps might lead to error. The author speaks of the light varying inversely as the square of the distance. That is true in the case of point source, but not true of line source. If the light is of any appreciable length in proportion to the tank, or the vehicle which is used in conveying the water, it will vary more nearly in inverse proportion to the distance, which will make a difference in some cases.

Theodore A. Leisen: The question of water purification is assuming such an important aspect throughout the whole country that any system of this kind will be welcome to all engineers interested in water supply. There are a few questions I would like to ask in regard to the result; first of all, as to the effect of a certain degree of turbidity of the water on the results of sterilization through the ultra-violet rays, and also the effect of color in the water; in other words, the ratio of increased consumption of current due to the increase in the turbidity of the water. My reason for asking that is that the question will come up as to the applicability of this system to waters where filtering may not be considered necessary as a means of clarification. I think that is notably the case in Detroit, at least as far as my experience goes. The water is reasonably free from turbidity, the actual turbidity scale running about 10 to 30 parts in the million, and for clarification purposes filtration would not really be necessary if a sterilizing medium could be applied that would act without the necessity of filtering in advance. I do not know what the turbidities go up to here in certain times of storm, in the case of the lake water, possibly too high to apply it without previous filtering. The water here is free from color, so that the color question would not enter into the discussion, except as a general matter of information. Mr. von Recklinghausen has said that, unfortunately for the power plants, the amount of current is very small; of course, that acts inversely, as far as the water department is concerned—the less current we have to use for sterilizing purposes the better satisfied we are. Our interests are not always identical.

From the commercial point of view the ultra-violet ray method of sterilization will have to come into competition with the use of certain chemicals, notably, calcium hypochlorite, which is being used extensively at the present time, and used very successfully. If, however, we can substitute a system of the kind described here, it will be very well, for the reason that it does away with all legitimate objections to any mixture of chemicals into the drinking water supplied. The use of hypochlorite of lime will unquestionably produce satisfactory results, so far as elimination of bacteria is concerned. If it is used in too large quantities, it

is likely to impart an odor and possibly a taste to the water, which is objectionable, and from the esthetic point of view, if from no other, the ultra-violet ray would be far more satisfactory than the hypochlorite of lime, but, from the commercial point of view, one must compete with the other, to a certain extent; and it would be very interesting from the water works man's point of view, at least, to get some definite figures as to the actual cost per million gallons of water sterilized by means of the ultra-violet rays.

I believe that almost any city would be willing to spend a little more money in the cost of operating a plant to sterilize the water by means of ultra-violet rays than it would to sterilize the water by means of hypochlorite of lime, or any other chemical agent, but if the difficrence is too great, it is always going to be a question which system will be adopted. Here in Detroit the question will come up for consideration very soon. The matter of filtration has been discussed more or less during the last few years, and I assume that one of the problems which will devolve upon me to settle is whether we are compelled to put in a filtration plant or not. If we could substitute a system of the kind described, in place of the filtration plant, it would be a great advantage to the city and probably result in considerable economy. If the filtering plant is necessary in the first instance, it might be a question whether a sufficiently high degree of purity could not be obtained by filtering alone, without resorting to ultra-violet rays at all, although it is an admitted fact that no filtering gives absolutely pure water. On a percentage basis, we can show beautiful results, and on a practical basis we show good results. The average mechanical filter, assuming aluminum sulphate or sulphate of iron is the coagulating medium, will in almost every instance give a reduction of from 99 to 99.9 per cent, which is almost as near absolute purity as you are likely to get under ordinary conditions. The chart referred to here, showing the reduction in typhoid fever cases, is an interesting one, and one along the same line was shown by us. I would like to ask whether during the preceding years, 1908 to 1912, filtration alone was in use in that city, or whether they used raw water—in other words, when the filter plant was first started, in distinction to the time when the ultra-violet ray system was started.

If Mr. von Recklinghausen can give any figures as to cost, I am sure they will be very interesting to everbody concerned in the subject of water supply.

William B. Jackson: I wish to ask whether the sterilization by the ultra-violet ray does not come into direct competition with the sterilization by ozone, the same as it does with sterilization by chemicals; and if so, whether Mr. von Recklinghausen can give us any idea as to the relative cost of sterilization under the two conditions of operation. I would also be interested to learn whether there is any definite understanding of the physiological effect of the ultra-violet rays upon the germs, that is,

whether the germs are supposed to be killed by heat or poison, or what the effect may be.

M. von Recklinghausen: Regarding the variation of the power of light, I can state that the law of the square of the distance holds about true, although some absorption of light in the air has to be added, also correction has to be made for the line shape of the lamp.

To the interesting remarks of Mr. Leisen, who is one of the foremost water experts in this country, I would like to reply as follows: If turbidity consists of particles which are bigger than a microbe, it might shield the microbe. If turbidity particles are smaller than the microbe—for example, as in the case of the Mississippi water—I do not think they will shield it. I think that such very fine turbidity will act like a color in solution, that is to say as an absorbent, and reduce the abiotic action, at a certain distance, to a certain degree, which can be determined very closely. In my experience, very fine so-called colloidal clay in water acts just like color in water. We have worked with such turbidities up to twenty parts per million, and have had about as good sterilization in that case as in working with low turbidities.

This was worked out in a very small plant, so I am unfortunately unable to indicate the amount of power which this amount of turbidity would need on a large scale. If turbidity consists of coarse suspended matter, I believe it will depend on the size and character of this suspended matter whether it will handicap sterilization or not. It will surely shield some microbes, but it is most likely that these microbes, due to the stirring action of the sterilizer, will at some other moment not be shielded when passing through the illuminated zone, and will therefore be killed.

Let us take another case, of very heavy particles—suppose we take the effluent from a sewer; it is most likely that visible particles flowing in the sewer water will themselves be full of microbes and heavily infected inside. I think it is out of the question that the rays will strike, during a few seconds' exposure, the microbes hidden in the inside of such particles, and I think, that, *a priori*, heavy floating particles handicap sterilization if those particles are themselves polluted and contain germs. The light must be able to strike the microbe at its first, second or third, etc., passage through the illuminated zone. If that microbe is hidden every time it passes through the light it is not killed.

I understand that here in Detroit the turbidity of the water which is taken from Lake St. Clair right near Belle Isle is usually pretty good and does not show turbidity much higher than 10 most of the year. I understand that, however, during certain storms, the silt at the bottom of Lake St. Clair, which is pretty shallow, is stirred up and the turbidity is very high—I am not sure of the figures, but understand it is 250 parts per million—

that it is practically like coffee. I am certain that such water could not be directly treated with ultra-violet rays, because they would penetrate only a few millimeters, and after that they would surely be held up by either one or the other of these particles. Therefore, I think in a case like Detroit it seems to be necessary to filter the water at least during some months of the year, but possibly during ten or eleven months it need not be done.

Now, as to the question of competition—and this will be partly in reply to Mr. Leisen's question, also—I know that hypochlorite of lime is used to disinfect the water, and I think it will always be a little cheaper to take a barrel of hypochlorite of lime and stir it up with water, and drop it into the drinking water. I have no doubt about that, but you must consider that in the case of a waterworks plant, particularly a small waterworks plant, you cannot do this unless you have a chemist, or some expert, following the matter of addition of these chemicals to the water right along very carefully, so as to avoid giving the water a bad taste or imparting an odor to it. I think that you will find the application of these disinfectants will come pretty high if you include the amount of intelligent labor necessary to follow such applications. Besides, we have to consider the objection on the part of the public to the use of obnoxious chemicals in its drinking water.

In reply to Mr. Leisen's remarks regarding the cost of treatment per million gallons, it will depend on the original condition of the water. The waters which I have seen coming from the modern mechanical filters are of such an ideal physical purity, that is to say, there is such a decided absence of suspended matter and color, as I have never seen in waters in Europe. If the physical condition of the water is as perfect as this, I am persuaded that—although, of course, I could not say I could guarantee it—it would be hardly necessary to use more than 30 kw-hr. per million gallons to do the work, and if you use 50 kw-hr. per million gallons, as I stated in the paper, you have a safety coefficient which I think it is desirable and even imperative to have in hygienic work. I do not know what a kilowatt-hour can be made for, but call it one cent, then 30 cents per million gallons would probably be sufficient. There is another expense to be considered—that the lamps have to be renewed from time to time. I doubt if this will come to more than just the same sum, so that I think the total cost would be about 60 cents per million gallons. Now, in the case of chemicals, with all the intelligent supervision, etc., the cost may be a little less, but, as Mr. Leisen said, I do not think it is a question merely of dollars and cents, but a question of giving decent water to the public, and even if the total cost should run a few cents higher, I do not think a modern city would hesitate to do something for the welfare of the people and deliver always decent water.

I have not yet been able to get a plant running in this country in connection with one of these modern mechanical filters, which

give, according to my laboratory tests, such ideal and perfect conditions. It may be, therefore, that the figures of consumption I give are somewhat exaggerated.

Regarding the typhoid records in Luneville, France, up to 1911 they used spring water, without purification. In 1912 they started to filter the Meurthe River water, and added spring water to it, using practically 90 per cent of the river supply, and there was some falling off in typhoid cases at that time, as you see from the chart, due to the mere filtration of the water, at the rate of seven million gallons per acre, with some previous roughing. The fact that the typhoid cases have gone down to zero, since sterilization was applied, I think is due to the fact that sterilization does not let any coli, the indicator of germs of intestinal diseases, get through at all. I know that hygienic statistics have to extend over ten years to be really reliable, and you have to get statistics from many places. I am sorry that our industry is too young to give ten years' tests, and I can only give you those which I have at my disposal.

I have another case of a small plant which I showed you on the screen, where the same results were obtained; typhoid is prevalent all around that country, which is a suburb of Rouen, France. All round they used the same kind of water, and there was a good deal of typhoid in that district. Since the sterilizing plant has been put in there has not been a case of typhoid for two years—as the statement, which I have from the Health Office of the town, shows.

Now we come to the question of competition from another source—ozone. Ozone has not been used much in this country. It has been used to a certain extent in Europe to act as a sterilizing agent, and I think difficulties are encountered, not so much on the question of whether ozone sterilizes or not, but on the question—Do you produce ozone or do you produce something else? It is known that a slight amount of humidity in the air which is subjected to the ozonator, will produce something else than ozone, namely, nitrous acid, which is not a sterilizing agent, and therefore the results of the plants which are in actual service prove rather discouraging from the bacteriological point of view. From the economy point of view, I would only refer to one set of tests, which were made by the Aquedotto Nicolai in Genoa, for about six months. This trial plant supplies about a thousand tons of water per day, and the water was treated alternately by ultra-violet rays, and by an ozone plant. The current consumption was practically the same with the ultra-violet rays plant and the ozone plant, but in the latter case only so far as the ozonator is concerned, not counting the cost of moving the water to the ozonator and the cost of forcing the ozonized air through the water. Taking it altogether, I think the power used is less with the ultra-violet rays. In the case mentioned, the report says that the ultra-violet rays can be run by a little girl, while the ozone plant needs an engineer.

William B. Jackson: What is the relative first cost of the plants?

M. von Recklinghausen: I cannot tell you the relative cost of the plants, as I do not know the cost of the ozone plant. I know in this case—I suppose they are all different—the original cost was 2.5 times as much, but I do not know whether that would account for all costs. I do not want to give that figure as the real figure. What is needed is the machine necessary for ozonizing, the high-frequency alternator, high-frequency transformer, and then the maintenance of the dielectrics, which blow out from time to time, etc.

William B. Jackson: Does the ozone work better on muddy water?

M. von Recklinghausen: There is one thing strange about practically all sterilizing agents, and that is that they all must be used only on practically clear water. In the case of ultra-violet rays, there is the physical necessity of having the rays strike the microbes. In the case of any chemical sterilization like ozone or hypochlorite of lime, you need much more of the chemical, in the case of the water being muddy, than when the water is clear. I think that is because some of the sterilizing—that is, the oxidizing—agent is used up by the organic mud, and you need much more ozone, etc., to penetrate into the organic matter than if such floating matter or even organic matter in solutionis absent.

The last question asked was: what the real effect was. Like many biological things, we do not know. If you expose water for a long time to ultra-violet rays, you might get a slight amount of peroxidation therein. This so formed disinfectant could not however, account for the sterilizing action of the rays, owing to the short period of time that the rays act on the germs. The amount of hydrogen peroxide generated by the light shining on the water is perhaps one millionth of what would be needed to produce enough peroxidation to act as a sterilizing agent. If we submit a germ to the ultra-violet light and look at it under the microscope, after having exposed it for a long time, we find its plasma coagulated,. therefore many will say that the action is coagulation of the plasma. After just enough exposure to ultra-violet light, however, the germs appear to be identical with living ones, except that their motil ty has gone. I think the exposure necessary, for instance, under the pistol lamp, to kill the bacteria, is one-twentieth of a second. I doubt whether you can make a complete chemical change in that microbe during that short time.

Alfred Herz: Is the microbe permanently killed, or only stunned?

M. von Recklinghausen: Permanently killed.

Alfred Herz: Any record of that?

M. von Recklinghausen: I need only mention the many tests made in Europe on plants for getting sterile water for

surgical work. They want water which has no microbes, and they make a very strict test, which consists in taking 100, 200 or 300 cu. cm. of the sterile water and mixing it with sterile broth. They put these samples under the most favorable temperature conditions for the microbes to develop. After several weeks, if the microbe contained in that broth has not developed, they come to the conclusion that it is dead, and such results have been obtained over and again with water which had been freed of its often very rich content of germs by short exposure to the ultra-violet rays.

Ind.

MEETING IN NEW YORK, DEC. 11, 1914. See page 315, Section I

PROCEEDINGS

OF THE

American Institute

OF

Electrical Engineers

Volume XXXIII
Number 12

DECEMBER, 1914

Per Copy, $1.00
Per Year, $10.00

Section I.—Institute Affairs

CONTENTS OF SECTION I

Section II.—Papers, Discussions and Reports

FOR CONTENTS OF SECTION II SEE TITLE PAGE OF SECTION II

Entered as matter of the second class at the post-office, New York, N.Y., December 17, 1904, under the Act of Congress, March 3, 1879.


KANSAS CITY
TERMINAL
DAYS KERITE
KERITE
DAYS KERITE
KERITE USED THROUGHOUT FOR POWER,
LIGHTING, SIGNALLING AND INTERLOCKING
KERITE INSULATED WIRE & CABLE COMPANY
© Kerite Ins. W. & C. Co. N.Y.

ALPHABETICAL LIST OF ADVERTISERS.

(For Classified List of Advertisers see page XI)

EDUCATIONAL INSTITUTIONS.

Classified List of Advertisers.

NOTE: For refecence to the advertisements see the Alphabetical List of Advertisers on page III.

ACCUMULATORS, ELECTRICAL.
Edison Storage Battery Co., Orange, N. J.
Westinghouse Machine Co., East Pittsburg, Pa.

AIR COMPRESSORS.
General Electric Co., Schenectady, N. Y.
National Brake & Electric Co., Milwaukee, Wis.
Westinghouse Traction Brake Co., New York

AMMETERS AND VOLTMETERS.
General Electric Co., Schenectady, N. Y.
Johns-Manville Co,, H. W., New York.
Wagner Electric Mfg. Co., St. Louis, Mo.
Western Electric Co., All Principal Cities.
Westinghouse Elec. and Mfg. Co., Pittsburg, Pa.
Weston Electrical Instrument Co., Newark, N. J.

ARRESTERS, LIGHTNING.
General Electric Co., Schenectady, N. Y.
Johns-Manville Co,, H. W., New York.
Westinghouse Elec. and Mfg. Co. Pittsburg, Pa.

BOOKS.
Van Nostrand Co., D., New York.

BRAKES, CAR.
General Electric Co., Schenectady, N. Y.
National Brake & Electric Co., Milwaukee, Wis.
Westinghouse Traction Brake Co., Pittsburg Pa.

CABLE CONNECTORS AND TERMINALS
Dossert & Co., New York.

CIRCUIT BREAKERS.
Cutler-Hammer Mfg. Co., Milwaukee, Wis.
General Electric Co., Schenectady, N. Y.
Johns-Manville Co., H. W.
Western Electric Co., All Principal Cities.
Westinghouse Elec. and Mfg. Co., Pittsburg, Pa.

CLUTCHES, MAGNETIC.
Cutler-Hammer Clutch Co., Milwaukee, Wis.

CONDUITS.
G. & W. Electric Specialty Co., Chicago, Ill.
Johns-Manville Co., H. W.
Johns-Manville Co., H. W., New York

CONTRACTORS.
Sanderson & Porter, New York.
White & Co., J. G., New York.

(Continued on page XI)

Classified List of Advertisers—*Continued.*

(Continued from page IX)

CONTROLLERS.
Cutler-Hammer Mfg. Co., Milwaukee, Wis.
General Electric Co., Schenectady, N. Y.
Westinghouse Elec. and Mfg. Co., Pittsburg, Pa.

CRANES AND HOISTS.
General Electric Co., Schenectady, N. Y.

CUT-OUTS.
General Electric Co., Schenectady, N. Y.
G. & W. Elec. Spec. Co., Chicago, Ill.
Westinghouse Elec. and Mfg. Co., Pittsburg, Pa.

DYNAMOS.
See Generators and Motors.

EDUCATIONAL INSTITUTIONS.
Rensselaer Polytechnic Institute, Troy, N.Y.
Syracuse University, Syracuse, N. Y.

ELECTRIC LOCOMOTIVES.
General Electric Co., Schenectady, N. Y.
Westinghouse Elec. & Mfg. Co., Pittsburg, Pa.

ENGINEERS.
Arnold, Bion J., Marquette Bldg., Chicago, Ill.
Barstow, W. S., 56 Pine St., New York,
Bates, Putnam A., 42 Broadway, New York. N. Y.
Ford, Bacon & Davis, 115 Broadway, N. Y.
Gati, Bela, Budapest, Hungary.
Jackson, Dugald C. & W. B., Chicago, Ill. and Boston, Mass.
Marshall, Wm., 709 Lexington Ave., New York.
McNeill, Ralph, 223 W. 106th St., New York.
Neall, N. J., Boston, Mass.
Neiler, Rich & Co., Inc., Manhattan Bldg., Chicago, Ill.
Sanderson & Porter, 52 William St., New York.
Sargent & Lundy, Railway Exchange Bldg. Chicago, Ill.
Sprague, Frank J., 20 Broad St., New York.
Thomas, P. H., 2 Rector St., New York.
White & Co., J. G., 43 Exchange Place, New York, N. Y

ENGINES, GAS AND STEAM.
Westinghouse Machine Co., East Pittsburg, Pa.

FANS ELECTRIC.
Fort Wayne Electric Works, Fort Wayne, Ind.
General Electric Co., Schenectady, N. Y.
Western Electric Co., All Principal Cities
Westinghouse Elec. and Mfg. Co., Pittsburg Pa.

FIBRE.
Johns-Manville Co., H. W., New York.

FUSES.
General Electric Co, Schenectady, N. Y.
Johns-Manville Co., H. W., New York.

GALVANOMETERS.
Weston Electrical Instrument Co., Newark, N. J.

GAS ENGINES.
Westinghouse Machine Co., East Pittsburg, Pa.

GENERATORS.
Fort Wayne Elec. Works, Fort Wayne, Ind.
General Electric Co., Schenectady, N. Y.
National Brake & Electric Co., Milwaukee, Wis.
Western Electric Co., All Principal Cities.
Westinghouse Elec. and Mfg. Co., Pittsburg.

INSTRUMENTS, ELECTRICAL.
General Electric Co., Schenectady, N. Y.
Wagner Electric Mfg. Co., St. Louis, Mo.
Western Electric Co., All Principal Cities.
Westinghouse Elec. and Mfg. Co., Pittsburg, Pa.
Weston Electrical Instrument Co., Newark, N. J.

INSULATION, MOLDED.
Cutler-Hammer Mfg. Co., Milwaukee, Wis.
Electrose Mfg. Co., Brooklyn, N. Y.
General Electric Co., Schenectady, N. Y.
Johns-Manville Co., H. W., New York.
Westinghouse Elec. & Mfg. Co., Pittsburg, Pa.

INSULATORS AND INSULATING MATERIAL.
Brookfield Glass Co., New York.
Cutler-Hammer Mfg. Co., Milwaukee, Wis.
Electrose Mfg. Co., Brooklyn, N. Y.
General Electric Co., Schenectady, N. Y.
Johns-Manville Co., H. W., New York.
Westinghouse Elec. & Mfg. Co., Pittsburg, Pa.
Western Electric Co., All Principal Cities.

LABORATORIES.
Electrical Testing Laboratories, 556 East 80th St., New York.

LAMPS, ARC.
Fort Wayne Electric Works, For Wayne, Ind.
General Electric Co., Schenectady, N. Y.
Western Electric Co., All Principal Cities.
Westinghouse Elec. & Mfg. Co., Pittsburg. Pa.

(Continued on page XIII)

Classified List of Advertisers—*Continued.*

(Continued from page XI)

LIGHTNING ARRESTERS.
General Electric Co., Schenectady, N. Y.
Johns-Manville Co., H. W., New York.
Westinghouse Elec. and Mfg. Co., Pittsburg, Pa.

LOCOMOTIVES, ELECTRIC.
Baldwin Locomotive Works, Philadelphia, Pa.
General Electric Co., Schenectady, N. Y.
Westinghouse Elec. and Mfg. Co., Pittsburg, Pa.

METERS, ELECTRIC.
Fort Wayne Electric Works, Fort Wayne, Ind.
General Electric Co., Schenectady, N. Y.
Johns-Manville Co., H. W., New York.
Western Electric Co., All Principal Cities.
Westinghouse Elec. and Mfg. Co., Pittsburg, Pa.
Weston Electrical Instrument Co., Newark, N. J.

MOTORS.
Fort Wayne Electric Works, Fort Wayne, Ind.
General Electric Co., Schenectady, N. Y.
National Brake & Electric Co., Milwaukee, Wis.
Wagner Electric Mfg. Co., St. Louis, Mo.
Western Electric Co., All Principal Cities.
Westinghouse Elec. and Mfg. Co., Pittsburg, Pa.

PANEL BOARDS.
General Electric Co., Schenectady, N. Y.
Western Electric Co., All Principal Cities.

PATENTS.
Clement, Edw. E., McGill Bldg., Washington, D. C.
Rosenbaum, Stockbridge & Borst, 41 Park Row, New York.
Townsend & Decker, 141 Broadway, New York.
Zabel, Max W., 1362 Monadnock Block, Chicago.

PUBLICATIONS, TECHNICAL.
Van Nostrand Co., D., New York, N. Y.

PUMPS.
Goulds Mfg. Co., Seneca Falls, N. Y.

RHEOSTATS.
Cutler-Hammer Mfg., Co., Milwaukee, Wis
General Electric Co., Schenectady, N. Y
Western Electric Co., All Principal Cities.
Westinghouse Elec. and Mfg. Co., Pittsburg, Pa.

SOCKETS AND RECEPTACLES.
Cutler-Hammer Mfg. Co., Milwaukee, Wis.

SOLENOIDS, MAGNETIC.
Cutler-Hammer Mfg. Co., Milwaukee, Wis.

STOKERS, MECHANICAL.
Westinghouse Machine Co., East Pittsburg, Pa.

STORAGE BATTERIES.
See Accumulators, Electrical.

SWITCHBOARDS, WOOD FOR.
Johns-Manville Co., H. W., New York.

SWITCHBOARDS.
Fort Wayne Electric Works, Fort Wayne, Ind.
General Electric Co., Schenectady, N. Y.
Western Electric Co., All Principal Cities.
Westinghouse Elec. and Mfg. Co., Pittsburg, Pa.

TELEPHONES.
Western Electric Co., All Principal Cities.

TRANSFORMERS.
General Electric Co., Schenectady, N. Y.
National Brake & Electric Co., Milwaukee Wis.
Wagner Electric Mfg. Co., St. Louis, Mo.
Westinghouse Elec. and Mfg. Co., Pittsburg, Pa.

TRUCKS, STORAGE BATTERY AUTO.
Westinghouse Machine Co., East Pittsburg, Pa.

TURBINES, STEAM.
General Electric Co., Schenectady, N. Y.
Western Electric Co., All Principal Cities.
Westinghouse Machine Co., East Pittsburg, Pa.

WATTMETERS.
Fort Wayne Electric Works, Fort Wayne, Ind.
General Electric Co., Schenectady, N. Y.
Johns-Manville Co., H. W., New York.
Westinghouse Elec. and Mfg. Co., Pittsburg, Pa.
Weston Electrical Instrument Co., Newark, N. J.

WIRES AND CABLES.
Aluminum Company of America, Pittsburg, Pa.
General Electric Co., Schenectady, N. Y.
Kerite Insulated Wire & Cable Co., 30 Church St., New York.
Roebling Sons' Co., John A., Trenton, N. J.
Standard Underground Cable Co., Pittsburg, Pa.
Simplex Wire & Cable Co., Boston, Mass.
Western Electric Co., All Principal Cities

Free Public Reference Library of Engineering

33 West Thirty-ninth Street, New York

THE AMERICAN INSTITUTE OF MINING ENGINEERS.
THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.
THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

The large number of accessions to the library during the last two years has made a very complete file of trade catalogues which have been classified according to subjects, and the names of the companies issuing them. These are now available for reference by those who may be interested.

The library has further extended its field of usefulness in the direction of bibliographical research work, which it is now prepared to undertake. Upon request a typewritten list of references to books or periodicals will be made on any subject covered in mining, mechanical and electrical engineering. Copying and translating work will also be done.

The work of cataloguing is still in progress, and when completed will render the resources of the library, comprising a collection of 50,000 volumes of engineering literature, easily accessible to members and patrons.

The following volumes are needed to complete sets, and the library would be pleased to secure these either by gift, exchange or purchase.

Aluminum World. Vols. 1-7, 1894-1900.
American Foundrymen's Association Journal. Vol. 1-3, Vol. 4, pp. 1-273; Vol. 5, Nos. 26, 28; Vol. 6, Nos. 31-35; Vol. 7, No. 41; Vol. 8, No. 48.
American Gas Light Journal. Vols. 1-11; 13, 68.
American Machinist. Vols. 1-2, 1878-9.
American Society of Naval Engineers. Journal. Vol. 1, pt. 1-2, 1889.
Beton und Eisen. Vol. 1-2, 1902-03.
Chemical Engineer, Chicago. Vols. 1-4.
Chemical Society, London. Journal. Vols. 1-26.
Deutsche Chemische Gesellschaft. Berichte. Vols. 1-6, 1868-74.
Elektrotechnische Zeitschrift. Vol. 7, No. 5, 1886; Vol. 19, No. 48, 1898.
Engineering Record. Vol. 1-3, No. 21; Vol. 17-18.
Factory. Vol. 3, No. 3, 1909; Vol. 4, No. 2, 1910.
Foundry. Vols. 4-22, 1894-1902.
Gas Engine, New York. Vol. 1-2, 1899-1900.
General Electric Review. Vol. 4, No. 1; Vol. 7, No. 4; Vol. 8, Nos. 2-3.
Le Genie Civil, Paris. Vol. 32; Vol. 52, No. 6.
Iron Trade Review. Vols. 1-27, 31, 34.
Jern Kontorets Annaler. Vol. 2, 4, 13, 16, 17; New series Vol. 5-11, 14-15.
Journal of Physical Chemistry. Vols. 1-5, 1897-1901.
Mining and Scientific Press. Vols. 1-9, 11-19, 24-33, 1860-69, 1872-76.
Municipal Engineering. Vols. 1-21, 25-30, 1890-1901, 1903-06.
Neues Jahrbuch fur Mineralogie, Geognosie, Geologie und Petrefaktenkunde. 1830-38.
Power. N. Y. Vols. 1-6, 1879-85.
Practical Engineer, London. Vols. 5-6, 1888-89.
Progressive Age. Vols. 1-8.
Science. New series. Vols. 1-6, 9-13.
Scientific American. 1st series. Vol. 1; Vol. 2, Nos. 1-2, 1845-46.
Sibley Journal of Engineering. Sibley College, Cornell University. Vols. 1-5.
Societe de l'Industrie Minerale. Compte Rendu. All before 1876, Jan.-April, June-Dec. 1877; 1878; Jan.-March 1879.
Vereins deutscher Ingenieur. Zeitschrift. Vols. 1-5.
Zeitschrift fur angewandte Chemie. Vol. 3 1889.

Communications may be addressed to the **Secretary of the American Institute of Electrical Engineers**, 33 West 39th Street, New York City:


ROEBLING